

HANDBOOK
of
BIOLOGICAL DATA

Editor: SPECTOR

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HANDBOOK of BIOLOGICAL DATA

EDITED BY
WILLIAM S. SPECTOR

Prepared under the Direction of the Committee
on the Handbook of Biological Data
DIVISION OF BIOLOGY AND AGRICULTURE
THE NATIONAL ACADEMY OF SCIENCES
THE NATIONAL RESEARCH COUNCIL

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Foreword

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Seven years ago the National Academy of Sciences-National Research Council contracted with the Wright Air Development Center, United States Air Force, to gather and compile for publication, in handbook form, basic established data in the biological and medical sciences. The principal objective of the Handbook, like that of similar volumes in the fields of engineering and physical sciences, is to serve the student, the teacher, and the expert who seeks information outside his own area of specialization. Another aim has been to produce as comprehensive a work as possible and, at the same time, keep it from becoming unwieldy in size and prohibitive in cost. To achieve this goal it has been necessary to condense some 20,000 sheets of data into the present number of tables, and, further, to condense each table to the point where only the most generally useful, informative, and comprehensive material would be included. Therefore, the data as presented are by no means complete, and the limitations of space and time have disallowed inclusion of many subjects of obvious importance.* Also, by the very nature of the subject material, certain of the tables will appear elementary to the expert in the field, while to the student — a beginner in the subject of the table — or to an expert in another field, the same data may seem extremely complex. For the compiler, who cannot possess an expert knowledge of all fields in the bio-sciences, the task of choosing for publication not only the subject areas, but also data within these areas, would have been utterly impossible without the unprecedented cooperation of some 17,000 biological scientists who gave freely of their time to serve as advisers, appraisers, contributors, and reviewers.

From the onset of the project, direction of the work was entrusted to the Committee on the Handbook of Biological Data, operating under the Division of Biology and Agriculture of the National Research Council. Membership of the Committee is representative of major fields in the biological sciences. The Committee, seeking the highest degree of authenticity, recognized that a specialist in a given field can best exercise the critical judgment necessary for evaluation of data in that field. He is also best able to identify those values derived from the most acceptable methods of measurement and those having the greatest likelihood, or actual history, of reproducibility in competent hands. The Committee accordingly prescribed that in selection and review of data, broadest collaboration be sought among outstanding investigators in each of the many areas of the biological sciences.

With the generous assistance of the Council's Office of Scientific Personnel, a "Panel of Appraisers," comprised of thousands of experts statistically proportioned into groups in relation to the various bio-science populations, was established to submit and grade table titles for inclusion in the Handbook and to suggest names of authorities to act as contributors. Each contributor to the Handbook was recommended by at least three experts in his field. Data received in the Handbook Office were compiled and reconciled into the Handbook format and resubmitted to the original contributors, as well as to a review panel — one panel for each table — for verification and authentication. By this procedure it has been possible to strip from the tables most of the questionable or borderline material, leaving for final presentation to the user only what is considered as fact or accepted as reliable theory by those who are competent to judge.

The tables in this Handbook represent the actual correlated contributions of more than 4,000 scientists and the counsel of an additional 13,000. In the face of this overwhelming response and devotion to the science, the compiler feels humble indeed.

The Handbook of Biological Data was prepared under USAF Contract No. 33(038)-2174 between the National Academy of Sciences and the Wright Air Development Center — to which funds were also contributed by the Department of the Army and the Department of the Navy — and Contract No. AT(49-1)-626 between the National Academy of Sciences and the Atomic Energy Commission. The first of the two contracts was administered under the direction of the Aero Medical Laboratory as Project 7158, Dr. J. W. Heim, Project Director, and the second, by Dr. John C. Bugher, former Director, Division of Biology and Medicine, Atomic Energy Commission.

Acknowledgment is made, on behalf of the Handbook Committee and the National Academy of Sciences-National Research Council, to Wright Air Development Center, Office of the Surgeon General of the Army, Office of Naval Research, and Division of Biology and Medicine of the Atomic Energy Commission, for the foresight and scientific judgment inherent in the commission to prepare this Handbook; to the scientists of the Smithsonian Institution for their most valuable assistance in problems of taxonomy; to the thousands of biologists all over the world who, as contributors and reviewers, made possible the completion of this edition; and to the thousands of others, unlisted, who so willingly responded to requests for advice. Acknowledgment is also made to the present and former members of the Handbook Staff for their loyalty to a most tedious and exacting task.

W. S. S.

Stacey
*These, as well as more detailed coverage of areas in this Handbook, will be published in monographs dealing with such special fields as growth and reproduction, circulation and respiration, plant and animal physiology, biophysical and biochemical characteristics, and aquatic biology. Already in print are "Standard Values in Blood" (1952), "Standard Values in Nutrition and Metabolism" (1954), and Volume I of a five-volume "Handbook of Toxicology."

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Introduction

"Without generalization there is no meaning, and without concreteness there is no significance."

... A. N. Whitehead

This Handbook presents tabular data and certain graphs, charts, and diagrams in the broad general areas of plant, animal, and pre-clinical medical sciences. The guiding principle for inclusion of material was its basic importance or wide general interest, and its adaptability to tabular presentation. The fact that certain of the data may already have been compiled and published was not regarded as a reason for excluding them from the Handbook. Unfortunately, some fundamental material has had to be omitted, either because in condensing 20,000 sheets of data into some 500 pages certain subject areas suffered extreme curtailment, or because efforts to secure the needed information were unsuccessful, or because certain tables arrived in the Handbook office too late to allow the processing requisite to publication. Inability to publish material that a contributor may have spent hours in compiling is cause for deepest regret, and every attempt will be made to include it in a revision of this volume or in one of the specialized monographs.

In considering presentational sequence of subject material, any one of a number of patterns could be followed. The one chosen appeared the most logical — first, chemical and physical data, then intra- or sub-cellular biology, followed by information on organs and organisms, growth and function, environmental effects, and, finally, distribution. The Table of Contents shows, for convenience of the user, a demarcation into ten categories. Within the book itself, however, no such clear-cut boundaries exist, and there is a gradual transition from one table or area to the next.

The chief objective in the preparation of this material in tabular form has been clarity of presentation. Where the subject matter of a table was considered to be inherently difficult for the non-specialist, effort has been made, in explanatory headnotes and footnotes, to resolve some of the difficulties. Certain of the tables contain symbols and terms peculiar to the fields of those tables. For each of these a glossary is included as an integral part of the table. In many instances information originally within the table itself has been moved into footnotes to simplify the structure of the table. Taxonomy, general definitions, symbols, and conversion factors, are covered in the Appendix.

One of the greatest difficulties encountered in the compilation of biological data is the element of variability. With few exceptions — and these clearly indicated — numerical values for variables are means, or adjusted means, of a group of measured values. To give these values significance, every effort has been made to present with the value an upper and lower estimate of the 95% range. The 95% range has been selected in preference to the standard deviation as better suited to the needs of the user who is not a specialist in the field from which a value has been drawn. The 95% range is a direct representation of the ordinary* range of variation, to be had only by further calculation if the standard deviation alone is available. The latter has the disadvantage of not being readily available, in many instances, and of giving biased limits for the 95% range when a variable has a skewed distribution. The statistically-minded reader who might wish to make further calculations from values in these tables may not care to proceed without facts on comparability and number of measurements. Unfortunately space does not permit including here such collateral information. Bibliographic references, available from the indicated contributor or from the Handbook Office, will lead to the original data where the desired material should be found.

The 95% range may be estimated in several ways, the method depending on the information available. The types of estimate most commonly encountered are listed below. The letter designations (a, b, c, d) will be found as superscripts identifying ranges given in the tables.** Range data as commonly encountered, including estimates of the 95% range, represent a mixture of the variability existing between individuals and the variability existing within individuals.

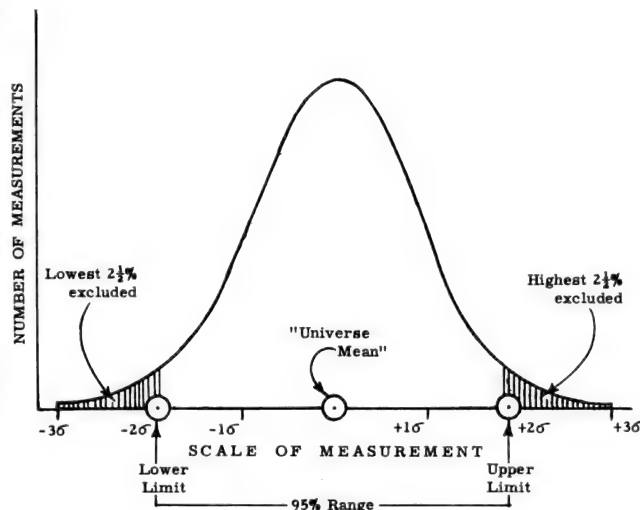
(a) By the method of greatest accuracy, the 95% range is obtained by fitting a recognized type of frequency curve to a group of measured values and excluding the extreme 2.5% of area under the curve at each end. (See sketch.) Estimate is made by this procedure only when the group of values is relatively large.

(b) By a less accurate method, the 95% range is estimated by a simple statistical calculation, assuming a normal distribution and using the standard deviation. This estimate is used when the group of values is too small for curve fitting, as is usually the case.

(c) A third and still less accurate procedure for gauging the 95% range is simply to take as range limits the highest value and lowest value of the reported sample group of measurements. It underestimates the 95% range for small samples (three or four values) and overestimates for larger sample sizes, but may be used in preference to the preceding method (b) when the sample shows convincing evidence that the variable is asymmetrical in distribution.

(d) The upper and lower limits of the ordinary range of variation, as estimated by an investigator experienced in measuring the quantity in question and based solely on general experience, constitute still another estimate of the 95% range. The reliability of limits so placed, although not as sound as with the methods listed above, should not be underestimated.

In some instances range data were not available; in others estimates of the 95% range are given, but information on the manner of estimate is lacking. Effort to assemble both types of missing information is continuing.



*To the clinician, equivalent, with reservations, to "normal and borderline."

**For details of these and other estimates the user is referred to standard texts on statistical methods.

QUESTIONNAIRE

TO THE USER OF

"THE HANDBOOK OF BIOLOGICAL DATA"

This volume is a first edition, comparable to first editions of other handbooks, particularly those in the physical sciences, in the sense that its initial presentation should offer a compilation not only useful in itself, but also one indicative of even greater service through improved future editions. Not yet subjected as a whole to the test of use and criticism by the scientific public, the book may be characterized by certain imbalances including areas treated too extensively or cursorily and remnant errors of commission or omission. We are convinced the persons best qualified to assist toward refined, superior future editions are those who, through study and use of this volume, have remarked such shortcomings. The following questions should receive particular attention by persons using this book. Your thoughts on them will be gratefully received at any time.

1. Has this first edition neglected to cover any general areas or specific tables, of fundamental usefulness to workers in the many biological sciences, that should be treated in a "handbook"?
2. Has it included areas not of this basic importance and utility, and of too specialized a nature for such a volume?
3. How might the coverage in certain areas, presently treated, be made more sound by expansion, contraction, or other types of revision?
4. Can gaps within specific tables be eliminated by incorporating material from the extant literature or from unpublished sources?
5. Are there typographical errors in any portion of the book, or definite errors of fact (i.e., values or statements you know to be untrue) that should be replaced in a revised edition?

If you are able to supplement your recommendations, we should appreciate receiving from you suggestions on sources of data needed for any revisions -- or preferably the data with references -- to modify, correct, or expand this initial presentation.

The Editor

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Washington, D. C.

TABLES

Data in each of the following tables are, in the judgment of the contributors and reviewers, established fact or recognized theory, free of controversial material, and represent the consensus of expert judgment and experience in the special field from which the table is drawn. It is recognized, however, that all biological data are subject to continuing revision as investigators improve techniques and make more measurements. The user of this book is warned against attributing significance to small differences among species, or even within the same species while uniformity in methods of measurement is yet to be attained, and, particularly, where there may be marked differences in the size, age, or condition of the test samples.

Improper balance in coverage, despite the best efforts of thousands of advisors, may still persist, and many gaps remain to be filled. An appeal is made, particularly to the teacher and the specialist, to advise the compiler on the inclusion of important basic information that has been omitted, or on the deletion of material that may, for one reason or another, be considered as less useful to the student or non-specialist.

The user in general -- from the beginner to the expert -- is invited to submit any values or ranges he feels should be given consideration. It is hoped that such persons will participate in the development of a second edition with improved balance, better coverage, and elimination of errors.

1. STANDARD SOLUTIONS: pH_s¹

Temp °C	HCl 0.1 M	Tetrox- alate ²	Tart- rate ³	Phtha- late ⁴	Phos- phate ⁵	Borax ⁶
1	0	1.10	1.67	4.01	6.98	9.46
2	5	1.10	1.67	4.01	6.95	9.39
3	10	1.10	1.67	4.00	6.92	9.33
4	15	1.10	1.67	4.00	6.90	9.27
5	20	1.10	1.68	4.00	6.88	9.22
6	25	1.10	1.68	3.56	6.86	9.18
7	30	1.10	1.69	3.55	6.85	9.14
8	35	1.10	1.69	3.55	6.84	9.10
9	40	1.10	1.70	3.54	6.84	9.07
10	45	1.10	1.70	3.55	6.83	9.04
11	50	1.10	1.71	3.55	6.83	9.01
12	55	1.11	1.72	3.56	6.84	8.99
13	60	1.11	1.73	3.57	6.84	8.96
14	70	1.11		3.59	6.85	8.92
15	80	1.11		3.61	6.86	8.88
16	90	1.12		4.20	6.86	8.85
17	95	1.12		4.22	6.87	8.83

/1/ pH_s is defined as $-\log f_{\text{H}^+}$, where f_{H^+} is the activity coefficient of hydrogen ion, and m_{H^+} is the concentration of hydrogen ion on the molal scale. /2/ 0.05M potassium tetroxalate. /3/ KHC₄H₄O₆, saturated solution at 25°C. /4/ 0.05M KHC₈H₄O₄. /5/ 0.025M KH₂PO₄ and 0.025M Na₂HPO₄. /6/ 0.01M.

2. ACID-BASE INDICATORS: pH RANGES

Indicator ¹	pH Range	Acid Color	Alkaline Color
1 Thymol blue (acid range)	1.2-2.8	Red	Yellow
2 Tropaeolin 00	1.3-3.2	Red	Yellow
3 Dimethyl yellow	2.9-4.0	Red	Yellow
4 Methyl orange	3.1-4.4	Red	Orange-yellow
5 Bromphenol blue	3.0-4.6	Yellow	Purple
6 Bromocresol green	3.8-5.4	Yellow	Blue
7 Methyl red	4.4-6.2	Red	Yellow
8 Bromthymol blue	6.0-7.6	Yellow	Blue
9 Phenol red	6.4-8.2	Yellow	Red
10 Neutral red	6.8-8.0	Red	Yellow
11 Thymol blue (alk. range)	8.0-9.6	Yellow	Blue
12 Phenolphthalein	8.0-9.8	Colorless	Red-violet
13 Thymolphthalein	9.3-10.5	Colorless	Blue
14 Alizarin yellow	10.1-11.1	Yellow	Lilac
15 Nitramine	10.8-12.8	Colorless	Orange-brown
16 Tropaeolin 0	11.1-12.7	Yellow	Orange-brown
17 Trinitrobenzoic acid	12.0-13.4	Colorless	Orange-red

/1/ A solution containing 0.1 percent indicator is satisfactory. Water is a suitable solvent for all the indicators listed except dimethyl yellow, neutral red, phenolphthalein, thymolphthalein, and nitramine; 70 - 90% ethanol should be used to dissolve these indicators.

3. BUFFER SOLUTIONS: pH RANGES

Acidic Component	Alkaline Component	pH Range
1 Hydrochloric acid	Glycine	1.0-3.7
2 Hydrochloric acid	Potassium hydrogen phthalate	2.2-4.0
3 Citric acid	Disodium hydrogen phosphate	2.2-8.0
4 Acetic acid	Sodium acetate	3.7-5.6
5 Potassium hydrogen phthalate	Sodium hydroxide	4.0-6.2
6 Potassium dihydrogen phosphate	Sodium hydroxide	5.8-8.0
7 Boric acid	Borax	6.8-9.2
8 Diethylbarbituric acid	Sodium diethylbarbiturate	7.0-9.2
9 Hydrochloric acid	Borax	7.6-9.2
10 Glycine	Sodium hydroxide	8.2-10.1
11 Borax	Sodium hydroxide	9.2-11.0
12 Disodium hydrogen phosphate	Sodium hydroxide	11.0-12.0

4. OXIDATION-REDUCTION (REDOX) POTENTIALS

E₀ at pH 7.0 and 30° C.

Indicator	E ₀ (volts)	Indicator	E ₀ (volts)
1 (Standard oxygen electrode)	+0.810	16 Galloxyanine	0.021
2 Phenol-m-sulfonate-indo-2,6-dichlorophenol	0.273	17 Methylene blue	0.011
3 m-Bromphenol indophenol	0.248	18 Janus green (a)	-0.011
4 o-Bromphenol indophenol	0.230	19 Ciba scarlet sulfonate	-0.036
5 Phenol indophenol	0.227	20 Pyocyanine	-0.040
6 Phenol blue	0.224	21 Indigo tetrasulfonate	-0.046
7 2,6-Dibromphenol indophenol	0.218	22 Methyl capri blue	-0.060
8 m-Cresol indophenol	0.208	23 Indigo trisulfonate	-0.081
9 o-Cresol indophenol	0.191	24 Nile blue	-0.122
10 Thymol indophenol	0.174	25 Gallophenine	-0.142
11 2,6-Dibromphenol indoguaiacol	0.159	26 Brilliant alizarine blue	-0.173
12 1-Naphthol-2-sulfonate indophenol	0.123	27 Phenosafranine	-0.252
13 Toluylene blue	0.115	28 Dimethyl phenosafranine	-0.260
14 Thionine (Lauth's violet)	0.063	29 Tetramethyl phenosafranine	-0.273
15 Brilliant cresyl blue	0.047	30 Safranine T	-0.289
		31 Neutral red	-0.325
		32 Viologens	-0.400
		33 (Standard hydrogen electrode)	-0.421

5. ORGANIC SYSTEMS: NORMAL OXIDATION-REDUCTION POTENTIALS

System	Potential E ₀ ¹ volts	pH
1 Epinephrine	0.808	0.0
2 Cytochrome a	0.29	7.4
3 Cytochrome c	0.26	5-8
4 Cytochrome b	-0.04	7.4
5 Reductone	0.282	0.0
6 2,6-Dichloroindophenol	0.217	7.0
7 Hemoglobin	0.152	7.0
8 Ascorbic acid	0.136	4.59
9 Methylene blue	0.011	7.0
10 Succinate-fumarate	-0.015	6.7
11 Pyocyanine	-0.034	7.0
12 Flavoprotein (yellow enzyme)	-0.059	7.0
13 Alcohol-acetaldehyde	-0.090	7.45
14 Hemin	-0.114	6.99
15 Lactate-pyruvate	-0.186	7.01
16 Riboflavin	-0.208	7.0
17 Phthiocol	-0.208	7.32
18 Cystine-cysteine	-0.227	7.15
19 Glutathione	-0.233	7.15
20 Coenzyme I	-0.325	7.4

/1/ Symbol used for systems in which H⁺ ions are involved.

6. IONIC SYSTEMS: NORMAL OXIDATION-REDUCTION POTENTIALS AT 25°C

Oxidation-Reduction System	Electrode Reaction	Normal Potential E ₀ , volts
1 Co ⁺⁺⁺ —Co ⁺⁺	Co ⁺⁺ = Co ⁺⁺⁺ + e	1.817
2 Ce ⁺⁺⁺ —Ce ⁺⁺	Ce ⁺⁺ = Ce ⁺⁺⁺ + e	1.55
3 Cl ₂ —Cl ⁻	Cl ⁻ = $\frac{1}{2}$ Cl ₂ + e	1.3583
4 Sn ⁺⁺⁺ —Sn ⁺⁺	Sn ⁺⁺ = Sn ⁺⁺⁺ + 2e	1.256
5 Ti ⁺⁺⁺ —Ti ⁺⁺	Ti ⁺⁺ = Ti ⁺⁺⁺ + 2e	1.211
6 Br ₂ —Br ⁻	Br ⁻ = $\frac{1}{2}$ Br ₂ + e	1.0648
7 Hg ₂ ⁺⁺ —Hg ⁺⁺	$\frac{1}{2}$ Hg ₂ ⁺⁺ = Hg ⁺⁺ + e	0.9011
8 O ₂ (1 atm.)—OH ⁻ at pH 7	OH ⁻ = $\frac{1}{2}$ H ₂ O + $\frac{1}{4}$ O ₂ + e	0.810
9 Fe ⁺⁺⁺ —Fe ⁺⁺	Fe ⁺⁺ = Fe ⁺⁺⁺ + e	0.7477
10 MnO ₄ ⁻ —MnO ₄ ⁼	MnO ₄ ⁼ = MnO ₄ ⁻ + e	0.664
11 I ₂ —I ⁻ Mn	I ⁻ = $\frac{1}{2}$ I ₂ + e	0.5345
12 Cu ⁺⁺ —Cu ⁺	Cu ⁺ = Cu ⁺⁺ + e	0.455
13 Ti ⁺⁺⁺ —Ti ⁺⁺	Ti ⁺⁺ = Ti ⁺⁺⁺ + e	0.37
14 H ₂ (1 atm.)—H ⁺	$\frac{1}{2}$ H ₂ = H ⁺ + e	0.0000 ¹
15 HCN + H ₂ O—HCNO + H ⁺	HCN + H ₂ O = HCNO + 2H ⁺ + 2e	0.0
16 Pb—Pb ⁺⁺	Pb = Pb ⁺⁺ + 2e	-0.126
17 Mn—Mn ⁺⁺	Mn = Mn ⁺⁺ + 2e	-1.1
18 Al—Al ⁺⁺⁺	Al = Al ⁺⁺⁺ + 3e	-1.7
19 Mg—Mg ⁺⁺	Mg = Mg ⁺⁺ + 2e	-2.4
20 K—K ⁺	K = K ⁺ + e	-2.924

/1/ Reference electrode.

7. ACIDS AND BASES: DISSOCIATION CONSTANTS
Values are for determinations at 25°C, unless otherwise indicated.

Acids				Bases			
Acid	Formula	Constant for 1st Hydrogen	Constant for 2nd Hydrogen	Base	Formula	Constant for 1st Hydroxyl	Constant for 2nd Hydroxyl
1 Acetic	C ₂ H ₄ O ₂	1.75 x 10 ⁻⁵		51 Acetamide	C ₂ H ₅ ON	3.1 x 10 ⁻¹⁵	
2 α-Alanine	C ₃ H ₇ O ₂ N	9 x 10 ⁻¹⁰		52 Acetanilide ³	C ₈ H ₉ ON	4.1 x 10 ⁻¹⁴	
3 Arsenic	H ₃ AsO ₄	5 x 10 ⁻³	4 x 10 ⁻⁵	53 α-Alanine	C ₃ H ₇ O ₂ N	5.1 x 10 ⁻¹²	
			6 x 10 ⁻¹⁰ (3H)	54 o-Aminobenzoic	C ₇ H ₇ O ₂ N	1.4 x 10 ⁻¹²	
4 Arsenious	HAsO ₂	6 x 10 ⁻¹⁰		55 Ammonium hydroxide	NH ₄ OH	1.8 x 10 ⁻⁵	
5 Barbituric	C ₄ H ₄ O ₃ N	1.05 x 10 ⁻⁴		56 Aniline	C ₆ H ₇ N	4.6 x 10 ⁻¹⁰	
6 Benzoic	C ₇ H ₆ O ₂	6.3 x 10 ⁻⁵		57 Arsenious oxide	As ₂ O ₃	1 x 10 ⁻¹⁴	
7 Boric	H ₃ BO ₃	6.4 x 10 ⁻¹⁰		58 Beryllium hydroxide	Be(OH) ₂		5 x 10 ⁻¹¹
8 Bromacetic	C ₂ H ₃ O ₂ Br	1.38 x 10 ⁻³		59 Brucine	C ₂₃ H ₂₆ O ₄ N ₂	7.2 x 10 ⁻⁴	2.5 x 10 ⁻¹¹
9 Butyric	C ₄ H ₈ O ₂	1.48 x 10 ⁻⁵		60 Butylamine, sec.	C ₄ H ₁₁ N	4.4 x 10 ⁻⁴	
10 Carbonic ¹	H ₂ CO ₃	3.5 x 10 ⁻⁷	4.4 x 10 ⁻¹¹	61 Caffeine ³	C ₈ H ₁₀ O ₂ N ₄	4.1 x 10 ⁻¹⁴	
11 Chloracetic	C ₂ H ₃ O ₂ Cl	1.4 x 10 ⁻³		62 Cinchonine ⁴	C ₁₉ H ₂₂ ON ₂	1.6 x 10 ⁻⁷	3.3 x 10 ⁻¹⁰
12 Citric	C ₆ H ₈ O ₇	8.4 x 10 ⁻⁴	1.8 x 10 ⁻⁵	63 Cocaine	C ₁₇ H ₂₁ O ₄ N	4 x 10 ⁻⁷	
			4 x 10 ⁻⁶ (3H)	64 Diethylbenzylamine	C ₁₁ H ₁₇ N	3.6 x 10 ⁻⁵	
13 Dichloroacetic	C ₂ H ₂ O ₂ Cl ₂	5 x 10 ⁻²		65 Diethylamine	C ₄ H ₁₁ N	1.26 x 10 ⁻³	
14 Formic	CH ₂ O ₂	1.76 x 10 ⁻⁴		66 Diisoamylamine	C ₁₀ H ₂₃ N	9.6 x 10 ⁻⁴	
15 Fumaric	C ₄ H ₄ O ₄	1 x 10 ⁻³	3 x 10 ⁻⁵	67 Diisobutylamine	C ₈ H ₁₉ N	4.8 x 10 ⁻⁴	
16 Hippuric	C ₉ H ₉ O ₃ N	2.3 x 10 ⁻⁴		68 Dimethylamine	C ₂ H ₇ N	5.2 x 10 ⁻⁴	
17 Hydrocyanic	HCN	7.2 x 10 ⁻¹⁰		69 Dimethylbenzylamine	C ₉ H ₁₃ N	1.05 x 10 ⁻⁵	
18 Hydroquinone ¹	C ₆ H ₆ O ₂	1.1 x 10 ⁻¹⁰		70 Dipropylamine	C ₆ H ₁₅ N	1.02 x 10 ⁻³	
19 Hydrosulfuric ¹	H ₂ S	9.1 x 10 ⁻⁸	1.2 x 10 ⁻¹⁵	71 Ethylamine	C ₂ H ₇ N	5.6 x 10 ⁻⁴	
20 Hydrazoic	HN ₃	1.9 x 10 ⁻⁵		72 Ethylenediamine	C ₂ H ₈ N ₂	8.5 x 10 ⁻⁵	
21 Hypochlorous ²	HOCl	3.7 x 10 ⁻⁸		73 Hydrazine	N ₂ H ₄ ·H ₂ O	3 x 10 ⁻⁶	
22 Iodic	HIO ₃	1.9 x 10 ⁻¹		74 Isoamylamine	C ₅ H ₁₃ N	5 x 10 ⁻⁴	
23 Isobutyric	C ₄ H ₈ O ₂	1.5 x 10 ⁻⁵		75 Isobutylamine	C ₄ H ₁₁ N	3.1 x 10 ⁻⁴	
24 Isovaleric	C ₅ H ₁₀ O ₂	1.7 x 10 ⁻⁵		76 Isopropylamine	C ₃ H ₉ N	5.3 x 10 ⁻⁴	
25 Lactic	C ₃ H ₆ O ₃	1.38 x 10 ⁻⁴		77 Lead hydroxide	Pb(OH) ₂		3 x 10 ⁸
26 Maleic	C ₄ H ₄ O ₄	1.5 x 10 ⁻²	2.6 x 10 ⁻⁷	78 Methylamine	CH ₅ N	5 x 10 ⁻⁴	
27 Malic	C ₄ H ₆ O ₅	4 x 10 ⁻⁴	9 x 10 ⁻⁶	79 Methyl-diethylamine	C ₅ H ₁₃ N	2.7 x 10 ⁻⁴	
28 Malonic	C ₃ H ₄ O ₄	1.61 x 10 ⁻³	2.1 x 10 ⁻⁶	80 α-Naphthylamine	C ₁₀ H ₉ N	9.9 x 10 ⁻¹¹	
29 Mandelic	C ₈ H ₈ O ₃	4.29 x 10 ⁻⁴		81 β-Naphthylamine	C ₁₀ H ₉ N	2 x 10 ⁻¹⁰	
30 Nicotinic	C ₆ H ₅ O ₂ N	1.4 x 10 ⁻⁵		82 o-Phenylenediamine	C ₆ H ₈ N ₂	3.3 x 10 ⁻¹⁰	
31 Nitrous ¹	HNO ₂	4 x 10 ⁻⁴		83 Phenylhydrazine ³	C ₆ H ₈ N ₂	1.6 x 10 ⁻⁹	
32 Oxalic	H ₂ C ₂ O ₄	6.5 x 10 ⁻²	6.1 x 10 ⁻⁵	84 Piperidine	C ₅ H ₁₁ N	1.6 x 10 ⁻³	
33 Periodic	HIO ₄	2.3 x 10 ⁻²		85 Propylamine (norm.)	C ₃ H ₉ N	4.7 x 10 ⁻⁴	
34 Phenol	C ₆ H ₆ O	1.3 x 10 ⁻¹⁰		86 Pyridine	C ₅ H ₅ N	2.3 x 10 ⁻⁹	
35 Phosphoric ¹	H ₃ PO ₄	1.1 x 10 ⁻²	7.5 x 10 ⁻⁸	87 Quinine ⁴	C ₂₀ H ₂₄ O ₂ N ₂	2.2 x 10 ⁻⁷	3.3 x 10 ⁻¹⁰
			4.8 x 10 ⁻¹³ (3H)	88 Quinoline	C ₉ H ₇ N	1 x 10 ⁻⁹	
36 Phosphorous	H ₃ PO ₃	7 x 10 ⁻³	2 x 10 ⁻⁵	89 Semicarbazide ³	CH ₅ ON ₃	2.7 x 10 ⁻¹¹	
37 Phthalic	C ₈ H ₆ O ₄	1.26 x 10 ⁻³	3.1 x 10 ⁻⁶	90 Silver hydroxide	AgOH	1.1 x 10 ⁻⁴	
38 Picolinic	C ₆ H ₅ O ₂ N	3 x 10 ⁻⁶		91 Strychnine ⁴	C ₂₁ H ₂₂ O ₄ N ₂	1 x 10 ⁻⁷	6 x 10 ⁻¹¹
39 Picric ¹	C ₆ H ₃ O ₇ N ₃	1.6 x 10 ⁻¹		92 Tetramethylenediamine	C ₄ H ₁₂ N ₂	5.1 x 10 ⁻⁴	
40 Propionic	C ₃ H ₆ O ₂	1.4 x 10 ⁻⁵		93 Thiourea	CH ₄ N ₂ S	1.1 x 10 ⁻¹⁵	
41 Salicylic	C ₇ H ₆ O ₃	1.06 x 10 ⁻³	1 x 10 ⁻¹³	94 m-Toluidine	C ₇ H ₉ N	5.5 x 10 ⁻¹⁰	
42 Selenious	H ₂ SeO ₃	3 x 10 ⁻³	5 x 10 ⁻⁸	95 o-Toluidine	C ₇ H ₉ N	3.3 x 10 ⁻¹⁰	
43 Succinic	C ₄ H ₆ O ₄	6.6 x 10 ⁻⁵	2.8 x 10 ⁻⁶	96 p-Toluidine	C ₇ H ₉ N	2 x 10 ⁻⁹	
44 Sulfanilic	C ₆ H ₇ O ₃ NS	6.2 x 10 ⁻⁴		97 Triethylamine	C ₆ H ₁₅ N	6.4 x 10 ⁻⁴	
45 Sulfuric ¹	H ₂ SO ₄	1.7 x 10 ⁻²	2 x 10 ⁻²	98 Triisobutylamine	C ₁₂ H ₂₇ N	2.6 x 10 ⁻⁴	
46 Sulfurous	H ₂ SO ₃	1.1 x 10 ⁻³	5 x 10 ⁻⁶	99 Trimethylamine	C ₃ H ₉ N	7.4 x 10 ⁻⁵	
47 Tartaric	C ₄ H ₆ O ₆	2 x 10 ⁻¹	6.9 x 10 ⁻⁵	100 Trimethylenediamine	C ₃ H ₁₀ N ₂	3.5 x 10 ⁻⁴	
48 Trichloroacetic ¹	C ₂ HO ₂ Cl ₃	2 x 10 ⁻¹		101 Tripropylamine	C ₉ H ₂₁ N	5.5 x 10 ⁻⁴	
49 Uric	C ₅ H ₄ O ₃ N ₄	1.5 x 10 ⁻⁶		102 Urea	CH ₄ ON ₂	1.5 x 10 ⁻¹⁴	
50 Valeric	C ₅ H ₁₀ O ₂	1.6 x 10 ⁻⁵		103 Zinc hydroxide	Zn(OH) ₂		1.5 x 10 ⁻⁹

1/ At 18°C. 2/ At 17°C. 3/ At 40°C. 4/ At 15°C.

8. AMINO ACIDS: IONIZATION CONSTANTS AND pH VALUES
Determinations were made at the isoelectric points of the amino acids in water at 25°C.

Amino Acid	Classical				Zwitterionic				Acidic				pH
	pK _{a1}	pK _{a2}	pK _{b1}	pK _{b2}	pK _{A1}	pK _{A2}	pK _{B1}	pF _{B2}	pK ₁	pK ₂	pK ₃	pK ₄	
1 DL-Alanine	9.866		11.649		2.348		4.131		2.348	9.866			6.107
2 L-Arginine	12.48		4.96	11.99	2.01		1.52	4.96	2.01	9.04	12.48		10.76
3 L-Aspartic acid	3.86	9.82	11.93		2.10	3.86	4.18		2.10	3.86	9.82		2.98
4 L-Cystine	8.00	10.25	11.95	12.96	1.04	2.05	3.75	6.00	1.04	2.05	8.00	10.25	5.02
5 L-Diiodotyrosine	6.48	7.82	11.88		2.12	6.48	6.18		2.12	6.48	7.82		4.29
6 L-Glutamic acid	4.07	9.47	11.90		2.10	4.07	4.53		2.10	4.07	9.47		3.08
7 Glycine	9.778		11.647		2.350		4.219		2.350	9.778			6.064
8 L-Histidine	9.18		7.90	12.23	1.77		4.82	7.90	1.77	6.10	9.18		7.64
9 Hydroxy-L-proline	9.73		12.08		1.92		4.27		1.92	9.73			5.82
10 DL-Isoleucine	9.758		11.679		2.318		4.239		2.318	9.758			6.038
11 DL-Leucine	9.744		11.669		2.328		4.253		2.328	9.744			6.036
12 L-Lysine	10.53		5.05	11.82	2.18		3.47	5.05	2.18	8.95	10.53		9.47
13 DL-Methionine	9.21		11.72		2.28		4.79		2.28	9.21			5.74
14 DL-Phenylalanine	9.24		11.42		2.58		4.76		2.58	9.24			5.91
15 L-Proline	10.60		12.0		2.00		3.40		2.00	10.60			6.3
16 DL-Serine	9.15		11.79		2.21		4.85		2.21	9.15			5.68
17 L-Tryptophan	9.39		11.62		2.38		4.61		2.38	9.39			5.88
18 L-Tyrosine	9.11	10.07	11.80		2.20	9.11	3.93		2.20	9.11	10.07		5.63
19 DL-Valine	9.719		11.711		2.286		4.278		2.286	9.719			6.002

9. CARBOHYDRATES: PHYSICAL AND CHEMICAL CHARACTERISTICS

Part I: NATURAL MONOSACCHARIDES: ALDOSES^{1,2}

Substance ³			Substance ³			Substance ³		
	MP °C	[α] _D , degrees ⁴		MP °C	[α] _D , degrees ⁴		MP °C	[α] _D , degrees ⁴
1 D-Glyceraldehyde (C ₃ H ₆ O ₃)		+13.5±0.5 (sirup)	64 L-Lyxose, 3-C-formyl-5-deoxy- (streptose) (C ₆ H ₁₀ O ₅) (concluded)	186-188	+26 (c 0.5, CH ₃ OH)	122 α-D-Xylose (C ₅ H ₁₀ O ₅) (concluded)	155-157	-40 [70°] (c 0.7, CH ₃ COOC ₂ H ₅)
2 D-Glyceraldehyde dimethyl acetal	BP ₁₄ , 124-127	+21.8 (c 6.5, H ₂ O)	65 2, 3-Di-O-acetyl-L-streptosonic acid monolactone	135-136	+14 (c 0.5, H ₂ O)	123 2, 4-Di-O-methyl-D-xylose anilide	170	-82 (dioxane)
3 2, 3-O-Isopropylidene-D-glyceraldehyde	BP _{0.8} , 18-20	+64.9 (c 5.7, C ₆ H ₆)	66 L-Streptosonic acid diamide	87	-23.1 → -23.7	124 Methyl 2, 4-di-O-methyl-3-O-p-tolylsulfonyl-β-D-xylopyranoside	88	-58.9 (c 1, CHCl ₃)
4 D-Glyceraldehyde dimethone	199-201	+197.5 (c 0.7, C ₂ H ₅ O)	67 D-Ribose p-bromophenylhydrazone	164-165	+10.3 (c 1, C ₂ H ₅ OH), 19.3 (c 1, C ₅ H ₅ N)	125 Methyl 2, 4-di-O-methyl-3-O-p-tolylsulfonyl-β-D-xylopyranoside	75-76	+28.8 (c 1, CHCl ₃)
5 D-L-Glyceraldehyde dimethone	197.5 (clouds at 190, melts at 210-211)		68 D-Ribose benzylphenylhydrazone	127-128	-26.5 (c 3, C ₂ H ₅ OH)	126 Methyl 2, 5-di-O-methyl-α-D-xylofuranoside	Sirup	+54.3
6 D-Glyceraldehyde 2, 4-dinitrophenylhydrazone	155-156		69 1, 2, 3, 5-Tetra-O-acetyl-D-ribofuranoside	82	-12.6 (c 12, CHCl ₃)	127 Methyl 2, 5-di-O-methyl-β-D-xylofuranoside	Sirup	-56 (c 2.3, CHCl ₃)
7 D-L-Glyceraldehyde 2, 4-dinitrophenylhydrazone	166-167		70 Tetra-O-acetyl-D-ribo-pyranoside	110	-52 (c 3, CHCl ₃)	128 2, 5-Di-O-methyl-D-xylofuranose	Sirup	+46 (c 1.2, H ₂ O)
8 D-L-Glyceraldehyde 2, 4-dinitrophenylazone anhydride	310-311		71 Methyl D-ribofuranoside	Sirup	+13.1 (c 1.9, CH ₃ OH)	129 Methyl 2, 5-di-O-methyl-3-O-p-tolylsulfonyl-α-D-xylofuranoside	Sirup	+34.7 [17°] (c 2, CHCl ₃)
9 D-Glyceraldehyde semicarbazone	133		72 Methyl D-ribofuranoside	83-84	-39.5 (CHCl ₃)	130 Methyl 2, 5-di-O-methyl-3-O-p-tolylsulfonyl-β-D-xylofuranoside	Sirup	-49.9 [18°] (c 1.8, CHCl ₃)
10 D-Glyceraldehyde, 3, 3-bis-C-(hydroxymethyl)- (apiose) (C ₅ H ₁₀ O ₅)		+5.6 (c 10) [150°] (sirup)	73 Methyl β-D-ribofuranoside	Sirup	-113.6 (c 1, H ₂ O)	131 Methyl 3, 4-di-O-methyl-β-D-xylopyranoside	89-90	-82 (c 2.1, CHCl ₃)
11 Apionic acid		-20 → -34.6 (H ₂ O)	74 Methyl 2, 3, 4-Tri-O-methyl-D-ribofuranoside	85-86	-35 (c 2.5, H ₂ O)	132 3, 4-Di-O-methyl-D-xylose	Sirup	+24.9 → +20.5 (c 2.2, H ₂ O)
12 Apionic acid phenylhydrazide	127	+30 (H ₂ O)	75 2, 3, 4-Tri-O-methyl-D-ribofuranoside	Sirup	+59.1 (c 4.7, CH ₃ OH)	133 Methyl 3, 4-di-O-methyl-2-O-p-tolylsulfonyl-β-D-xylopyranoside	105	-34.8 (c 1.6, CHCl ₃)
13 Apiose benzyl phenylhydrazone	137-138	-78.5 (c 5, C ₅ H ₅ N) [579]	76 Methyl 2, 3, 5-tri-O-methyl-D-ribofuranoside	Sirup	+41.1 (c 1, CH ₃ OH)	134 3, 5-Di-O-methyl-D-xylose	Sirup	+25 (c 1.1, H ₂ O)
14 β-D-Arabinose (C ₅ H ₁₀ O ₅)	155	-175 → -103 [16°]	77 2, 3, 5-Tri-O-methyl-D-ribofuranoside	56.5		135 Methyl 2, 3, 4-tri-O-methyl-β-D-xylopyranoside	49-50	-73 (c 0.8, CHCl ₃)
15 D-Arabinose benzylphenylhydrazone	177-178	+14.4 (CH ₃ OH) [16°]	78 2, 3, 5-Tri-O-methyl-D-ribose anilide			136 Methyl 2, 3, 4-tri-O-methyl-α-D-xylopyranoside (with some β?)	Sirup	+86 (c 2, CH ₃ OH)
16 D-Arabinose p-bromophenylhydrazone	163		79 β-D-Ribose, 2-deoxy- (D-erythro-2-deoxyaldo-pentose) (C ₅ H ₁₀ O ₄)	96-98	-91 → -58	137 2, 3, 4-Tri-O-methyl-α-D-xylopyranose	91-92	+64 → +18 (c 1, H ₂ O)
17 D-Arabinose diphenylhydrazone	206		80 2-Deoxy-D-ribose benzylphenylhydrazone	128	-17.5 (c 2, C ₅ H ₅ N)	138 Methyl 2, 3, 5-tri-O-methyl-D-xylofuranoside	Sirup	+32 (c 0.8, CH ₃ OH)
18 Tri-O-acetyl-β-D-arabopyranosyl	139	-283.4 (CHCl ₃)	81 2-Deoxy-D-ribose p-nitrophenylhydrazone	160	-11.1 [14°] (c 0.1, C ₂ H ₅ OH)	139 2, 3, 5-Tri-O-methyl-D-xylofuranose	Sirup	+24.7 → +29.5 (H ₂ O)
19 Methyl α-D-arabofuranoside	65-67	+123 (c 1.2, H ₂ O)	82 2-Deoxy-D-ribose anilide	175-176	+20.5 (C ₂ H ₅ OH)	140 1, 2, 3, 5-Tetra-O-acetyl-D-xylofuranoside	Sirup	+56 (C ₂ H ₅ OH)
20 Methyl β-D-arabopyranoside	168	-241.1 (H ₂ O)	83 1, 3, 4-Tri-O-acetyl-2-deoxy-D-ribofuranoside	98	-171.8 (c 0.5, CHCl ₃)	141 D-Allose, 6-deoxy- (C ₆ H ₁₂ O ₅)	140-143	+1.6 [18°] (c 0.6)
21 Methyl 2-O-methyl-β-D-arabinoside	62-63	-205 (c 1.6, CH ₃ OH)	84 Methyl 2-deoxy-D-ribofuranoside (α, β mixture)	Sirup	+38.4 (c 0.6, CH ₃ COOH)	142 6-Deoxy-D-allose p-bromophenylhydrazone	138-140	
22 2-O-Methyl-D-arabinose	Sirup	-102 (c 1.5, H ₂ O)	85 Methyl 3, 5-di-O-p-tolylsulfonyl-D-ribofuranoside (α, β mixture)	Sirup	-121 (c 0.4, CHCl ₃)	143 1, 2, 3, 4-Tetra-O-acetyl-6-deoxy-D-allopyranoside	109-110	+10.4 (c 2, CHCl ₃)
23 2-O-Methyl-D-arabinose p-toluenesulfonylhydrazone	143 d.	-17.0 (c 1, H ₂ O)	86 Methyl 3-4-di-O-p-tolylsulfonyl-β-D-ribofuranoside	104-107	-115.5 (c 6.7, CHCl ₃)	144 D-Allose, 2,6-dideoxy- (digitoxose) (2,6-dideoxy-D-altrose) (C ₆ H ₁₂ O ₄)	110	+46.4
24 2, 4-Di-O-methyl-D-arabinose	Sirup	-30.8 (c 2.4, H ₂ O)	87 D-Ribose, 2-C-hydroxymethyl- (hamamelose) (C ₆ H ₁₂ O ₆)	165-166	-7.1 [578]	145 Digitoxose phenylhydrazone	204-209	+215 (C ₅ H ₅ N, C ₂ H ₅ OH)
25 2, 4-Di-O-methyl-D-arabinose anilide	142-143	+80.4 (c 1.1, H ₂ O) [150°]	88 Hamamelose p-nitrophenylhydrazone	Sirup	+144 [578] (c 4, C ₅ H ₅ N)	146 Digitoxose oxime	102	
26 Methyl 2, 3, 5-tri-O-methyl-D-arabofuranoside	Sirup	+40 (c 2.9, CH ₃ OH) [14°]	89 Methyl hamameloside	72.5	-75 (c 5, CH ₃ OH)	147 D-Allose, 2,6-dideoxy-3-O-methyl- (cymarose) (C ₇ H ₁₄ O ₄)	93	+52
27 2, 3, 5-Tri-O-methyl-D-arabofuranose	Sirup		90 Methyl tri-O-acetyl hamameloside	152	-34.8 [Hg] (c 4.1, C ₂ H ₅ OH)	148 Methyl α-D-cymaroside	34-36	+210±2 [14°] (c 1.3, CH ₃ OH)
28 α-L-Arabinose (C ₅ H ₁₀ O ₅)	158 amorph.	+55.4 → +105	91 Ammonium hamamelonate		-3.9 [578] (c 10, H ₂ O)			
(See also β-D-arabinose for hydrazones and bromides)								
29 β-L-Arabinose (C ₅ H ₁₀ O ₅)	160	+190.6 → 104.5						

	(See also β -D-arabinose for hydrazones and bromides)			92	Hamamelonic acid phenylhydrazide	202-203	+35.2 [578] (c 4, 50% CH ₃ COOH, C ₅ H ₅ N)	149	α -Cymaronic acid phenylhydrazide	155-156	+1.4 \pm 3, [16°] (c 0.7, CH ₃ OH)
30	Tetra-O-acetyl- α -L-arabopyranoside	97	+42.5 (c 3, CHCl ₃)					150	Antiarose (C ₆ H ₁₂ O ₅)		Levo -30
31	Tetra-O-acetyl- β -L-arabopyranoside	86	+147.2 (c 5, CHCl ₃)	93	α -D-Xylose (C ₅ H ₁₀ O ₅)	145	+93.6 \rightarrow +18.8	151	Antiaronic acid lactone		
32	2, 3, 4, 5-Tetra-O-acetyl-L-arabinose	113-115	-65.6 (c 4, CHCl ₃)	94	D-Xylose p-nitro phenylhydrazide	156		152	Antiaronic acid phenylhydrazide	143-145	
33	Methyl α -L-arabofuranoside		-125 (c 1.2, H ₂ O)	95	D-Xylose benzylphenylhydrazide	99	-20.3 (CH ₃ OH)	153	α -D-Galactose (C ₆ H ₁₂ O ₆) See β -D-galactose	167	+150.7 \rightarrow +80.2
34	Methyl α -L-arabopyranoside	131	+17.3 (c 3, H ₂ O)	96	D-Xylose p-bromophenylhydrazide	128	-20.7 (H ₂ O)	154	β -D-Galactose (C ₆ H ₁₂ O ₆) D-Galactose o-tolylhydrazide	176	+52.8 \rightarrow +80.2
35	Methyl β -L-arabopyranoside	166-169	+245 (c 7, H ₂ O)	97	1, 2, 3, 4-Tetra-O-acetyl- α -D-xylopyranoside	59	+89.3 (c 5, CHCl ₃)	155	D-Galactose p-bromophenylhydrazide	166-167	
36	Methyl 2-O-methyl- β -L-arabopyranoside	63-65	+208 (c 2.5, CH ₃ OH)	98	1, 2, 3, 4-Tetra-O-acetyl- β -D-xylopyranoside	128	-24.7 (c 5, CHCl ₃)	156	D-Galactose p-nitrophenylhydrazide	196-197	
37	2-O-Methyl-L-arabinose	Sirup	+100 (c 5, H ₂ O)	99	2, 3, 4, 5-Tetra-O-acetylaldehyde-D-xylose	87-89	-15.9 [26°] (c 4, CHCl ₃)	157	D-Galactose benzylphenylhydrazide	157-158	
38	2-O-Methyl-L-arabinose phenylhydrazide	114-116		100	Methyl D-xyloside (furanose form?)	Sirup	+62.8 (C ₂ H ₅ OH)	158	2, 3, 4, 5, 6-Penta-O-acetylaldehyde-D-galactose	121	-25 [26°] (c 4, CHCl ₃)
39	3-O-Methyl-L-arabinose	Sirup	+110 (c 3.6, H ₂ O)	101	Methyl α -D-xylopyranoside	90-92	+153.9 (c 11, H ₂ O)	160	1, 2, 3, 5, 6-Penta-O-acetyl- α -D-galactofuranoside	87	+61.2 (c 4, CHCl ₃)
40	3-O-Methyl-L-arabinose anilide	117		102	Methyl β -D-xylopyranoside	157	-65.5 (c 13, H ₂ O)	161	1, 2, 3, 5, 6-Penta-O-acetyl- β -D-galactofuranoside	98	-41.6 (CHCl ₃)
41	2, 3-Di-O-methyl-L-arabinose	Sirup	+107 (c 1, H ₂ O)	103	Methyl 2-O-methyl- β -D-pyranoside	111-112	-67.7 (c 1.4, CHCl ₃)	162	1, 2, 3, 4, 6-Penta-O-acetyl- α -D-galactopyranoside	96	+106.7 (c 3, CHCl ₃)
42	2, 3-Di-O-methyl-L-arabinose anilide	139		104	2-O-Methyl- β -D-xylose	132-133	-23.9 \rightarrow +35.9 (c 4, H ₂ O)	163	1, 2, 3, 4, 6-Penta-O-acetyl- β -D-galactopyranoside	142	+25 (CHCl ₃)
43	2, 4-Di-O-methyl-L-arabinose	Sirup	+30.8 ⁵	105	3-O-Methyl- α -D-xylose	103-104	+55 \rightarrow +17 (c 2, H ₂ O)	164	Methyl α -D-galactopyranoside monohydrate	110	+179.3 (c 9, H ₂ O)
44	Methyl 2, 5-di-O-methyl-L-arabofuranoside	Sirup	-60 (c 1, H ₂ O)	106	3-O-Methyl- α -D-xylose	95	+45 \rightarrow +19 (c 1.6, H ₂ O)	165	Methyl β -D-galactopyranoside	178	0 (c 10, H ₂ O)
45	2, 5-Di-O-methyl-L-arabinose	Sirup	-2 (c 1, H ₂ O)	107	3-O-Methyl- α -D-xylose	98-101		166	Methyl 2-O-methyl- α -D-galactopyranoside	Sirup	+180 (c 3.5, CH ₃ OH)
46	Methyl 3, 4-di-O-methyl- β -L-arabopyranoside	Sirup	+210.6 (c 3.8, CHCl ₃)	108	3-O-Methyl-D-xylose anilide	137		167	Methyl 2-O-methyl- β -D-galactopyranoside	131-132	+1.7 (c 11, H ₂ O)
47	3, 4-Di-O-methyl-L-arabinose	Sirup	+116 (c 4.2, H ₂ O)	109	5-O-Methyl-D-xylose	Sirup	+32.8 \rightarrow +36 (c 2, H ₂ O)	168	2-O-Methyl- β -D-galactopyranose	147-149	+53 \rightarrow +86.2 (c 5, H ₂ O)
48	Methyl 2, 3, 4-tri-O-methyl- α -L-arabopyranoside ⁶	46-48	+46.2 (c 1, H ₂ O)	110	1, 2-O-Isopropylidene-3-O-p-tolylsulfonyl-5-O-methyl-D-xylose	81-82	-31.8 (c 2.4, CHCl ₃)	169	Methyl 3-O-methyl- β -D-galactopyranoside	Sirup	+31.9 (c 5, H ₂ O)
49	Methyl 2, 3, 4-tri-O-methyl- β -L-arabopyranoside ⁶	44-46	+250 (c 1, H ₂ O)	111	Methyl 3-O-p-tolylsulfonyl-5-O-methyl- β -D-xylofuranoside	89	-51.7 [18°] (c 1.8, CHCl ₃)	170	α -D-Galactopyranose, 3-O-methyl- (C ₇ H ₁₄ O ₆)	144-147	+150.6 \rightarrow +108.6
50	2, 3, 4-Tri-O-methyl-L-arabinose	Sirup	+127 (c 8, H ₂ O)	112	Methyl 3-O-p-tolylsulfonyl-5-O-methyl- α -D-xylofuranoside	Sirup	+44.5 [17°] (c 2.2, CHCl ₃)	171	4-O-Methyl- β -D-galactopyranose	207	+62 \rightarrow +92 (c 1.5, H ₂ O)
51	2, 3, 5-Tri-O-methyl-L-arabinose	Sirup	0 (c 1, H ₂ O)	113	Methyl 2, 3-di-O-methyl-D-xyloside (α form?)	Sirup	+61.8 (c 1.2, CH ₃ OH)	172	Methyl 6-O-methyl- β -D-galactofuranoside (?)	Sirup	-78.7 (c 3.3, H ₂ O)
52	Tri-O-acetyl- β -L-arabopyranosyl bromide	139	+287.1 (c 2, CHCl ₃)	114	Methyl 2, 3-di-O-methyl-D-xyloside (β form?)	Sirup	-5.8 (c 2.2, CHCl ₃)	173	6-O-Methyl- α -D-galactopyranose	113-114	+137 \rightarrow +77 (c 3, H ₂ O)
53	D-, L-Arabinose (C ₅ H ₁₀ O ₅) (See D- and L-arabinose for derivatives)	163.5-164.5	None	115	2, 3-Di-O-methyl-D-xylose (α form?)	79-80	+70 \rightarrow +23 (c 1, H ₂ O) [15°]	174	Methyl 2, 3-di-O-methyl- α -D-galactopyranoside	Sirup	+210 (H ₂ O)
54	α -L-Lyxose (C ₅ H ₁₀ O ₅)	105	+5.8 \rightarrow +13.5	116	Methyl 2, 3-di-O-methyl-4-O-p-tolylsulfonyl- β -D-xylopyranoside	56-59	-8.8 (c 2.5, CHCl ₃)	175	Methyl 2, 3-di-O-methyl- β -D-galactopyranoside	Sirup	+23 (H ₂ O)
55	L-Lyxose p-bromophenylhydrazide	157		117	Methyl 2, 4-di-O-methyl- β -D-xylopyranoside	77.5-78.5	-70 (c 1, CHCl ₃)	176	2, 3-Di-O-methyl- β -D-galactopyranose	Sirup	+57 \rightarrow +105 (H ₂ O)
56	L-Lyxose p-nitrophenylhydrazide	172		118	Methyl 2, 4-di-O-methyl- β -D-xylopyranoside	60-61	-82.4 (c 1.4, CHCl ₃)	177	Methyl 2, 4-di-O-methyl- α -D-galactopyranoside	105	+142 (c 1.1, H ₂ O)
57	Tetra-O-acetyl- α -D-lyxose ⁷	93-94	+25 (CHCl ₃)	119	2, 4-Di-O-methyl-D-xylose (β form?)	108	-30 \rightarrow +22 (H ₂ O)	178	Methyl 2, 6-di-O-methyl- β -D-galactopyranoside	165-166	0 (c 1.8, H ₂ O)
58	Methyl α -D-lyxopyranoside ⁷	108-109	+59.4 (c 5, H ₂ O)	120	2, 4-Di-O-methyl-D-xylose	111	-13 \rightarrow +23 (c 2, H ₂ O)	179	2, 4-Di-O-methyl- β -D-galactopyranose	103	+122 \rightarrow +85.6 (c 1.7, H ₂ O)
59	Methyl β -D-lyxopyranoside ⁷	118	-128.1 (c 2, H ₂ O)	121	2, 4-Di-O-methyl-D-xylose	116-118	-26 (c 1, CHCl ₃)	180	Methyl 2, 6-di-O-methyl- β -D-galactopyranoside	72	-22 (c 1, CHCl ₃)
60	Methyl 2, 3, 4-tri-O-methyl-D-lyxoside ⁷	Sirup	+10 [5461] (c 2.6, H ₂ O)					181	2, 6-Di-O-methyl- β -D-galactopyranose	106-108	+45 \rightarrow +88 (c 5.4, H ₂ O)
61	2, 3, 4-Tri-O-methyl-D-lyxose ⁷	79	-10 \rightarrow -22 (c 2, H ₂ O)								
62	2, 3, 5-Tri-O-methyl-D-lyxose ⁷	Sirup	+39 (c 1, H ₂ O)								
63	L-Lyxose, 3-C-Formyl-5-deoxy- (streptose) (C ₆ H ₁₀ O ₅) L-Streptosonic acid monolactone	146-148	-37 (c 0.7, H ₂ O)								

9. CARBOHYDRATES: PHYSICAL AND CHEMICAL CHARACTERISTICS (Continued)

Part I: NATURAL MONOSACCHARIDES: ALDOSES^{1,2} (Continued)

Substance ³			Substance ³			Substance ³		
	MP °C	[α] _D , degrees ⁴		MP °C	[α] _D , degrees ⁴		MP °C	[α] _D , degrees ⁴
182			182			289		
α-D-Galactopyranose, 3-O-methyl (C ₇ H ₁₄ O ₆) (concluded)	128-130	+46.8 → +87.5 (c 6.3, H ₂ O)	L-Galactose (C ₆ H ₁₂ O ₆) (See derivatives of α-galactose)		(See α-galactose)	β-D-Glucose (C ₆ H ₁₂ O ₆) (concluded)	156-158	+110 → +65.7 (c 4, H ₂ O)
2,6-Di-O-methyl-β-D-galactopyranose	102-103	-9.1 (c 6.2, CHCl ₃)	234	82	+75 [14°] (c 5.6, H ₂ O)	4,6-Di-O-methyl-α-D-glucose	Sirup	+4.0 [32°] (c 2, H ₂ O)
183			L-Galactose ⁸ , 3,6-anhydro-(C ₆ H ₁₀ O ₅)			5,6-Di-O-methyl-β-D-glucose	Sirup	+50 (c 4, H ₂ O)
184			Methyl 2,4-di-O-methyl-3,6-anhydro-L-galactopyranoside	235		Methyl 2,3,4-tri-O-methyl-β-D-glucopyranoside	93-94	-19.6 (c 5, H ₂ O)
185			2,4-Di-O-methyl-3,6-anhydro-L-galactose	236		2,3,4-Tri-O-methyl-β-D-glucose	Sirup	+11 (c 1.8, H ₂ O)
186			Methyl 3,6-anhydro-β-L-galactoside	237		Methyl 2,3,5-tri-O-methyl-β-D-glucopyranoside	Sirup	+17 (c 1.8, H ₂ O)
187			α-L-Galactose, 6-deoxy-(L-fucose) (C ₆ H ₁₂ O ₅)	145	-124.1 → -76.4	2,3,5-Tri-O-methyl-β-D-glucose	Sirup	+149 (c 2, CH ₃ OH)
188			Methyl α-L-fucoside (See also α-galactose, 6-deoxy-)	154-156	-197 [15°] (c 1.1, H ₂ O)	Methyl 2,3,6-tri-O-methyl-β-D-glucopyranoside	58-60	-48 (c 5, CHCl ₃)
189			Methyl 3-O-methyl-α-L-fucopyranoside	130-132	-173 [14°] (c 0.4, H ₂ O)	2,3,6-Tri-O-methyl-α-D-glucose	121-123	+90 → +70.5 (H ₂ O)
190			3-O-Methyl-L-fucose	Sirup	-94 [15°] (c 0.5, H ₂ O)	Methyl 2,4,6-tri-O-methyl-β-D-glucopyranoside	70-71	-27.4 (c 5, CHCl ₃)
191			Methyl 2,3-di-O-methyl-α-L-fucopyranoside	49-51	-190 [15°] (c 1.4, H ₂ O)	2,4,6-Tri-O-methyl-α-D-glucose	123	+89.7 → +71.9 (c 2, H ₂ O)
192			2,3-Di-O-methyl-L-fucose	Sirup	+4.6 [15°] (c 3, H ₂ O)	Methyl 3,4,6-tri-O-methyl-β-D-glucopyranoside	52-53	-16.4 (c 2, CHCl ₃)
193			Methyl 3,4-di-O-methyl-α-L-fucopyranoside	100	-213 (c 1.3, H ₂ O)	3,4,6-Tri-O-methyl-α-D-glucose	76-77	+91.9 → +77.4 (c 2, H ₂ O)
194			3,4-Di-O-methyl-L-fucose	76, 82	-118 [15°] (c 1.1, H ₂ O)	3,4,6-Tri-O-methyl-β-D-glucose	97-98	+41.1 → +77.5 (c 1.6, H ₂ O)
195			Methyl 2,3,4-tri-O-methyl-α-L-fucopyranoside	97-98	-209 (H ₂ O)	Methyl 3,5,6-tri-O-methyl-α-D-glucopyranoside	Sirup	+93 (c 3.1, CH ₃ OH)
196			Methyl 2,3,4-tri-O-methyl-β-L-fucopyranoside	101.5 → 102.5	-21 (H ₂ O)	Methyl 3,5,6-tri-O-methyl-β-D-glucopyranoside	Sirup	-87 (c 2.8, CH ₃ OH)
197			2,3,4-Tri-O-methyl-α-L-fucose	36-37	-184 → -128 (H ₂ O)	3,5,6-Tri-O-methyl-β-D-glucose	Sirup	-25.9 (c 1, H ₂ O)
198			Methyl β-L-fucoside	120-122	+15.1 (c 2, H ₂ O)	Methyl tetra-O-methyl-α-D-glucopyranoside	Sirup	+147.2 (c 10, H ₂ O)
199			D,L-Galactose (C ₆ H ₁₂ O ₆) (See derivatives of α-galactose)	143-144, 163	None	Methyl tetra-O-methyl-β-D-glucopyranoside	40-41	-17.3 (c 4, H ₂ O)
200			α-D-Glucose (C ₆ H ₁₂ O ₆) (See β-D-glucose)	146	+112.2 → +52.7	Tetra-O-methyl-α-D-glucopyranose	88-89	+100 → +83.3 (c 5, H ₂ O)
201			α-D-Glucose monohydrate (C ₆ H ₁₂ O ₆ ·H ₂ O)	83	+102 → +47.9	Tetra-O-methyl-β-D-glucopyranose	50	+73.1 → +83.1 (c 5, H ₂ O)
202			D-Glucose p-bromophenylhydrazone (See also β-D-glucose)	164-166		Methyl tetra-O-methyl-α-D-glucopyranoside	11	+107 [18°] (c 0.7, H ₂ O)
203			β-D-Glucose (C ₆ H ₁₂ O ₆)	148-150	+18.7 → +52.7	Methyl tetra-O-methyl-β-D-glucopyranoside	Sirup	-72.7 (CH ₃ OH)
204			D-Glucose p-nitrophenylhydrazone	189	+21.5 (C ₅ H ₅ N, C ₂ H ₅ OH)	Tetra-O-methyl-β-D-glucopyranose	Sirup	-7.6 (c 0.9, H ₂ O)
205			D-Glucose benzylphenylhydrazone	150, 158		D-Glucose, 6-benzoyl-(vaccinin) (C ₁₃ H ₁₆ O ₇)	Amorph.	+48 (C ₂ H ₅ OH)
			Penta-O-acetyl-α-D-glucopyranose	114	+101.6 (c 5, CHCl ₃)	1,2,3,4-Tetra-O-acetyl-6-O-benzoyl-β-D-glucose	132	+32.9 (CHCl ₃)
			Penta-O-acetyl-β-D-glucopyranose	135	+3.8 (c 7, CHCl ₃)	D-Glucose ⁹ , 2-deoxy-(C ₆ H ₁₂ O ₅)	148	+46.6 [18°]
			Penta-O-acetyl-aldehyde-D-glucose	119-120	-4.2 (c 3, CHCl ₃)	2-Deoxy-β-D-glucose benzylphenylhydrazone	158-159	
206			Methyl α-D-glucopyranoside	62-63	+118 (c 5, H ₂ O)	α-D-Glucose, 2-deoxy-2-amino-(chitosamine) (glucosamine) (C ₆ H ₁₃ NO ₅)	88	+100 → +47.5

207	β -D-Galactosamine hydrochloride	187	+44.5 \rightarrow +80 (c 2, HCl-H ₂ O)	260	Methyl β -D-glucopyranoside	Sirup	-77 (H ₂ O)	318	α -D-Glucosamine hydrochloride		+100 \rightarrow +72.5
208	N-Acetyl-D-galactosamine	120-122	+115 \rightarrow +80 (H ₂ O)	261	Methyl α -D-glucopyranoside	166	+158.9 (c 10, H ₂ O)	319	β -D-Glucose, 2-deoxy-2-amino- (C ₆ H ₁₃ NO ₅)	110-111	+28 \rightarrow +47.5
209	N-(2, 4-Dinitrophenyl)-D-galactosamine	184-186	+84 [5461] (c 1, 80% C ₂ H ₅ OH)	262	Methyl β -D-glucopyranoside	105	-34.2 (c 10, H ₂ O)	320	β -D-Glucosamine hydrochloride		+25 \rightarrow +72.5
210	1, 3, 4, 6-Tetra-O-acetyl-N-acetyl- α -D-galactosamine	178	+102 (c 1.6, CHCl ₃)	263	Methyl 2-O-methyl- α -D-glucopyranoside	147-148	+155 (c 0.7, H ₂ O)	321	N-Acetyl-D-glucosamine	205	+64 \rightarrow +40.9 (H ₂ O)
211	1, 3, 4, 6-Tetra-O-acetyl-N-acetyl- β -D-galactosamine	235	+10 (c 1, CHCl ₃)	264	Methyl 2-O-methyl- β -D-glucopyranoside	97-98	-37.5 (c 5, H ₂ O)	322	N-(2, 4-Dinitrophenyl)-D-glucosamine	202-204	+65 [5461] (c 1, C ₂ H ₅ OH)
212	Methyl N-acetyl- α -D-galactosaminide	217-218	+170 (CHCl ₃)	265	2-O-Methyl- β -D-glucose	157-158	+2 \rightarrow +65.3 (c 2, H ₂ O)	323	N-(2-Hydroxy-1-naphthylidene)-D-glucosamine	202-203	+274 \rightarrow +217 [5461] (CH ₃ OH)
213	Methyl 3, 4, 6-Tri-O-methyl- α -D-galactosaminide hydrochloride	227	+150.3 (c 3.6, CH ₃ OH)	266	Methyl 3-O-methyl- β -D-glucopyranoside	Sirup	-26 (c 5.5, H ₂ O)	324	D-Glucosamine diphenylhydrazone	162	
214	3, 4, 6-Tri-O-methyl-D-galactosamine hydrochloride	178	+114 (c 1, H ₂ O)	267	3-O-Methyl- α -D-glucose	160-161	+104.3 \rightarrow +55.3 (c 1, H ₂ O)	325	Tetra-O-acetyl- α -D-glucosaminopyranoside	143	+25.9 (CHCl ₃)
215	Methyl 3, 4, 6-Tri-O-methyl-N-acetyl- α -D-galactosaminide	185	+121 (c 1.4, CHCl ₃)	268	3-O-Methyl- β -D-glucose	130-132	+31.9 \rightarrow +55.1 (c 1, H ₂ O)	326	Tetra-O-acetyl- α -D-glucosaminopyranoside hydrochloride	230	+29.7 (H ₂ O)
216	Methyl 3, 4, 6-Tri-O-methyl-N-acetyl- β -D-galactosaminide	232	+7 (c 1, CHCl ₃)	269	4-O-Methyl-D-glucose	Sirup	+53 (c 2, H ₂ O)	327	Tetra-O-acetyl-N-acetyl- α -D-glucosaminopyranoside	139-140	+93.4 (CHCl ₃)
217	N-(2-Hydroxy-1-naphthylidene)-D-galactosamine	175-178	+287 \rightarrow +258 (CH ₃ OH) [5461]	270	5-O-Methyl-D-glucose	Sirup	-10.6 (c 2, C ₂ H ₅ OH)	328	Tetra-O-acetyl-N-acetyl- β -D-glucosaminopyranoside	187-189	+1.2 (CHCl ₃)
218	α -D-Galactose, 6-deoxy- (D-fucose) (rhodose) (C ₆ H ₁₂ O ₅)	140-145	+127 \rightarrow +76.3 (c 10)	271	Methyl 6-O-methyl- α -D-glucopyranoside	Sirup	+127.9 (H ₂ O)	329	Tetra-O-acetyl-N-acetyl-aldehyde-D-glucosamine	156-157	+36 (c 0.1, CHCl ₃)
219	D-Fucose benzylphenylhydrazone	178-179	-14.9 (c 0.4, CH ₃ OH)	272	Methyl 6-O-methyl- β -D-glucopyranoside	133-135	-27.0 (c 5, H ₂ O)	330	Methyl N-acetyl- β -D-glucosaminofuranoside	Sirup	-25 (c 0.8, H ₂ O)
220	D-Fucose p-bromophenylhydrazone	184		273	6-O-Methyl- α -D-glucose	143-145	+110 \rightarrow +55 (c 3, H ₂ O)	331	Methyl α -D-glucosaminide hydrochloride	119	+127 (H ₂ O)
221	Methyl α -D-fucoside	155-156	+190 (c 4.2, H ₂ O)	274	Methyl 2, 3-di-O-methyl- α -D-glucopyranoside	80-82	+142.6 (c 5, H ₂ O)	332	Methyl β -D-glucosaminide hydrochloride	190	-24.2 (H ₂ O)
222	Methyl β -D-fucoside	120	-14.0 (c 0.8, H ₂ O)	275	Methyl 2, 3-di-O-methyl- β -D-glucopyranoside	62-64	-36.6 (c 5, H ₂ O)	333	Methyl N-acetyl- α -D-glucosaminide	188-189	+104 (H ₂ O)
223	2-O-Methyl-D-fucose	155-161	+73 \rightarrow +87 (c 1.3, H ₂ O)	276	2, 3-O-Methyl- α -D-glucose	85-87	+81.9 \rightarrow +48.3 (c 1, CH ₃ COCH ₃)	334	Methyl N-acetyl- β -D-glucosaminide	195-196	-43 (H ₂ O)
224	Methyl 2, 3, 4-Tri-O-methyl- β -D-fucopyranoside	93-98	+11.2 (c 1, H ₂ O)	277	2, 3-O-Methyl- β -D-glucose	108-110	+5.9 \rightarrow +50.9 (c 4, CH ₃ COCH ₃)	335	Methyl 3-O-methyl-N-acetyl- α -D-glucosaminide	211	+116 (H ₂ O)
225	2, 3, 4-Tri-O-methyl-D-fucose	Sirup		278	Methyl 2, 4-di-O-methyl- α -D-glucopyranoside	79-81	+159, +186 (c 0.3-1, CH ₃ COCH ₃)	336	3-O-Methyl- α -D-glucosamine hydrochloride	215 d.	+123 \rightarrow +91.3 (H ₂ O)
226	2, 3, 4-Tri-O-methyl- α -D-fucose hydrate	65	+106 (c 1, H ₂ O) +183 \rightarrow +128.8 (H ₂ O)	279	Methyl 2, 4-di-O-methyl- β -D-glucopyranoside	124	-16.5 [29°] (c 0.5, CH ₃ COCH ₃)	337	Methyl 4, 6-di-O-methyl-N-acetyl- β -D-glucosaminide	187	-21.5 [16°] (c 2.5, CH ₃ OH)
227	D-Galactose, 6-deoxy-3-O-methyl- (digitalose) (C ₇ H ₁₄ O ₅)	106, 119	+106 -83 (c 3.2, H ₂ O)	280	Methyl 2, 6-di-O-methyl- α -D-glucopyranoside	Sirup	+154 (c 1.5, H ₂ O)	338	Methyl 3, 4, 6-tri-O-methyl- α -D-glucosaminide	Sirup	+169.8 (c 0.8, CH ₃ OH)
228	Digitalonic acid lactone	137-138		281	Methyl 2, 6-di-O-methyl- β -D-glucopyranoside	50-52	-43.5 (c 11, CHCl ₃)	339	Methyl 3, 4, 6-tri-O-methyl- α -D-glucosaminide hydrochloride	237 d.	+129.6 (c 0.5, H ₂ O)
229	Methyl 3-O-methyl- α -D-fucopyranoside	Sirup	+124.4 (c 0.9, CH ₃ COCH ₃)	282	2, 6-Di-O-methyl-D-glucose	Sirup	+58.2 (c 2.7, H ₂ O)	340	Methyl 3, 4, 6-tri-O-methyl-N-acetyl- α -D-glucosaminide	150	+104.3 (c 0.9, H ₂ O)
230	Methyl 3-O-methyl- β -D-fucopyranoside	97-99		283	Methyl 3, 4-di-O-methyl- β -D-glucopyranoside	79-81	-11.9 (c 5, CHCl ₃)	341	Methyl 3, 4, 6-tri-O-methyl-N-acetyl- β -D-glucosaminide	195	+19.6 (c 0.3, CHCl ₃)
231	D-Galactose, 2, 6-dideoxy-3-O-methyl- (diginose) (C ₇ H ₁₄ O ₄)	90-92	+56 \pm 4 -30 [14°] (c 2, CH ₃ COCH ₃)	284	3, 4-Di-O-methyl- β -D-glucose	113	+64.9 \rightarrow +94.8 (c 1, H ₂ O)	342	3, 4, 6-Tri-O-methyl-D-glucosamine hydrochloride	210 d.	+49.2 \rightarrow +99.5 (c 1.2, H ₂ O)
232	Diginonic acid lactone	Sirup		285	Methyl 3, 6-di-O-methyl- β -D-glucopyranoside	Sirup	+55.4 (c 3.5, C ₂ H ₅ OH)	343	3, 4, 6-Tri-O-methyl-N-acetyl-D-glucosamine	234	+75 \rightarrow +44.8 (H ₂ O)
233	S-Benzylthiuronium salt of diginonic acid	137	-9.2 (CH ₃ OH)	286	3, 6-Di-O-methyl- α -D-glucose	113-116	+102.6 \rightarrow +61.5 (c 3, H ₂ O)	344	D-Glucose, 6-deoxy- (chinosose) (epirhamnose) (glucosamethylose) (isorhamnose) (isorhodose) (quinosose) (C ₆ H ₁₂ O ₅)	139-140	+73.3 \rightarrow +29.7 (c 8)
				287	Methyl 4, 6-di-O-methyl- α -D-glucopyranoside	Sirup	+157 (CHCl ₃)				
				288	Methyl 4, 6-di-O-methyl- β -D-glucopyranoside	50-52	-28 (c 3, CHCl ₃)	345	D-Glucosamethylosic acid lactone	151-152	+66.9 \rightarrow +5.4 (H ₂ O)

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Substance ³		MP °C	[α] _D , degrees ⁴	Substance ³		MP °C	[α] _D , degrees ⁴	Substance ³		MP °C	[α] _D , degrees ⁴
	β-D-Glucose, 6-deoxy- (chinoside)(epirhamnose) (glucumethylolose)(isorhamnose)(isorhodose)(quinoside)(C ₆ H ₁₂ O ₅) (concluded)	98-99		373	β-D-Mannose (C ₆ H ₁₂ O ₆) (continued)	64		404	β-D-Mannose (C ₆ H ₁₂ O ₆) (concluded)	24	
346	Methyl α-D-glucumethylolide	131-132	-55.1 (H ₂ O)	374	Penta-O-acetyl-α-D-mannopyranoside	117-118	+55 (c 4, CHCl ₃)	405	Tetra-O-methyl-α-D-mannofuranoside	Sirup	+98.6 [19°] (c 1, H ₂ O)
347	Methyl β-D-glucumethylolide	116	+84 → +33	375	Methyl α-D-mannofuranoside	118-119	-25.3 (c 3, CHCl ₃)	406	Methyl tetra-O-methyl-β-D-mannofuranose (?)	Sirup	+39 → +43 (c 0.5, H ₂ O)
348	α-D-Glucose, 6-deoxy-3-O-methyl- (D-thevetose) (C ₇ H ₁₄ O ₅)	121	+6 (CH ₃ COCH ₃)	376	Methyl α-D-mannopyranoside	193-194	113 (c 1, H ₂ O)	407	Methyl tetra-O-methyl-β-D-mannofuranoside	107-108	+24.7 (c 4, CH ₃ OH)
349	1, 2, 4-Tri-O-acetyl-3-O-methyl-β-D-glucumethylolide	105	+122 (CH ₃ COCH ₃)	377	Methyl β-D-mannopyranoside isopropyl alcoholate	74-75	79.2 (c 1, H ₂ O)	408	Tetra-O-methyl-γ-D-mannonolactone		+64.8 [40°] (c 1.7, H ₂ O)
350	1, 2, 4-Tri-O-acetyl-3-O-methyl-α-D-glucumethylolide	116-117	-44±2 (c 1, H ₂ O)	378	Methyl 2-O-methyl-α-D-mannofuranoside	82	-53.3 (c 4, H ₂ O)	409	α-L-Mannose, 6-deoxy-, monohydrate (L-rhamnose) (C ₆ H ₁₄ O ₆) (See β-L-mannose, 6-deoxy-)	93-94	-8.6 → +8.2
351	Methyl β-D-thevetoside	86-87	+148±2 (c 1, H ₂ O)	379	2-O-Methyl-D-mannose	136-137	+129.5 (c 2.6, H ₂ O)	410	β-L-Mannose, 6-deoxy- (L-rhamnose) (C ₆ H ₁₂ O ₅)	123-125	+38.4 → +8.9
352	Methyl α-D-thevetoside	141-143	-95.5 → -51.4	380	Methyl 4-O-methyl-α-D-mannopyranoside	101-102	+7.0 → +4.5 (c 2.9, H ₂ O)	411	L-Rhamnose p-bromophenylhydrazide	169-170	
353	α-L-Glucose (C ₆ H ₁₂ O ₆) (See α- and β-D-glucose)	130-132	-64	381	4-O-Methyl-α-D-mannose	127-129	+84.4±0.5 (c 0.8, H ₂ O)	412	L-Rhamnose p-nitrophenylhydrazide	190-191	-50 → -8.5 (C ₅ H ₅ N, C ₂ H ₅ OH)
354	L-Glucose, 2-deoxy-2-amino-N-methyl- (C ₇ H ₁₅ NO ₅)	160-163	-103 → -88 (c 0.6, H ₂ O)	382	6-O-Methyl-D-mannose	Sirup	+32.4 → +22.3 (c 4, H ₂ O)	413	L-Rhamnose benzylphenylhydrazide	121	-10.4 → -7.4 (CH ₃ OH)
355	N-Methyl-α-L-glucosamine hydrochloride	165-166	-51 (c 0.5, H ₂ O)	383	Methyl 2, 3-di-O-methyl-D-mannoside	Sirup	+15.3 (c 1.1, CHCl ₃)	414	Tetra-O-acetyl-β-L-rhamnopyranoside	98-99	+13.9 (c 15, C ₂ H ₅ Cl ₄)
356	N-Acetyl-N-methyl-L-glucosamine	160-161	-100 (c 0.7, CHCl ₃)	384	2, 3-Di-O-methyl-D-mannose	Sirup	+43.5 (c 2.4, CHCl ₃)	415	Methyl α-L-rhamnopyranoside	108-109	-62.5 (c 10, H ₂ O)
357	Tetra-O-acetyl-N-acetyl-N-methyl-α-L-glucosaminide	153	-16.5 (c 3, CHCl ₃)	385	Methyl 3, 4-di-O-methyl-α-D-mannopyranoside	80	+16, +22 (c 0.7-1.2, H ₂ O)	416	Methyl β-L-rhamnopyranoside	138-140	+95.4 (c 10, H ₂ O)
358	Tetra-O-acetyl-N-acetyl-N-methyl-β-L-glucosaminide	126-129	-36.9±2	386	3, 4-Di-O-methyl-α-D-mannose monohydrate	114	+88.6 [17°] (CHCl ₃)	417	Methyl 2-O-methyl-L-rhamnopyranoside	139-140	
359	L-Glucose, 6-deoxy-3-O-methyl- (thevetose) (C ₇ H ₁₄ O ₅)	118-119	-7.5±2 (c 1.1, CH ₃ COCH ₃)	387	Methyl 4, 6-di-O-methyl-α-D-mannopyranoside	Sirup	+22 → +4 (c 2, H ₂ O)	418	2-O-Methyl-L-rhamnose	113-114	+31 (H ₂ O)
360	1, 2, 4-Tri-O-acetyl-3-O-methyl-β-L-glucumethylolide	103-104	-113 (CH ₃ OH)	388	4, 6-Di-O-methyl-D-mannonic acid phenylhydrazide	151	+80.5 [5780] (c 1.2, H ₂ O)	419	Methyl 4-O-methyl-α-L-rhamnoside	Sirup	-50.2 (c 1.5, H ₂ O)
361	1, 2, 4-Tri-O-acetyl-3-O-methyl-α-L-glucumethylolide	62-63	+11.9±2.5	389	4, 6-Di-O-methyl-D-mannonic acid phenylhydrazide	Sirup	+25 [5780] (c 4.3, H ₂ O)	420	4-O-Methyl-L-rhamnose	125-126	+13 (c 1, CH ₃ OH)
362	L-Glucose, 2, 6-dideoxy-3-O-methyl- (D-oleandrose) (C ₇ H ₁₄ O ₄)	155-160	+20.3 (c 0.6, CH ₃ OH)	390	Methyl 2, 3, 4-tri-O-methyl-α-D-mannopyranoside	102-103	+14 [5780] (c 0.9, H ₂ O)	421	Methyl 5-O-methyl-L-rhamnopyranoside	59-60	-89.2 (c 1, H ₂ O)
363	Oleandrose 2, 4-dinitrophenylhydrazide	136	+12 → +15.6 (c 1.2, CH ₃ OH)	391	2, 3, 4-Tri-O-methyl-D-mannose	Sirup	+18.2 → +7 [5780] (c 20, H ₂ O)	422	5-O-Methyl-L-rhamnofuranoside	102-103	-4.3 (c 3, H ₂ O)
364	Oleandronic acid phenylhydrazide	78-79	+12 → +15.6 (c 1.2, CH ₃ OH)	392	Methyl 2, 3, 5-tri-O-methyl-D-mannofuranoside	Sirup	+54 [18°] (c 1.3, H ₂ O)	423	Methyl 2, 3-di-O-methyl-α-L-rhamnoside	Sirup	-6, -14 (c 2, H ₂ O)
365	β-D-Glucose, 2, 6-dideoxy-3-O-methyl- (sarmentose) ¹⁰ (C ₇ H ₁₄ O ₄)	146	+6.5±2 (c 1.2, CH ₃ OH)	393	Methyl 2, 3, 5-tri-O-methyl-γ-D-mannonolactone	118	+67 → +63.5 (c 1, H ₂ O)	424	2, 3-Di-O-methyl-L-rhamnose	136-138	
366	S-Benzyl-thiuronium salt of sarmentonic acid	133	+29.3 → +14.2	394	Methyl-2, 3, 6-tri-O-methyl-D-mannoside	Sirup	+26 (c 0.9, H ₂ O)	425	3, 4-Di-O-methyl-L-rhamnose	91-92	-10 → +18.6 (c 1.5, H ₂ O)
367	α-D-Mannose (C ₆ H ₁₂ O ₆) (See β-D-mannose)	132	-16.3 → +14.5	395	2, 3, 6-Tri-O-methyl-D-mannose	Sirup	-6.5 (c 0.6, H ₂ O)	426	3, 4-Di-O-methyl-L-rhamnose	98-99	+24 → +18.5 (c 0.5, H ₂ O)
368	β-D-Mannose (C ₆ H ₁₂ O ₆)	199-200	+26.3	396	2, 3, 6-Tri-O-methyl-γ-D-mannonolactone	84-85	+65.5 [18°] (c 1, H ₂ O)	427	Methyl 2, 3, 4-tri-O-methyl-L-rhamnopyranoside (α form?)	Sirup	-15.5 (H ₂ O)
369	D-Mannose phenylhydrazide	170-171	+29.8 (CH ₃ OH)	397	Methyl 2, 4, 6-tri-O-methyl-α-D-mannopyranoside	Sirup	+70 (c 1, H ₂ O)	428	Methyl 2, 3, 4-tri-O-methyl-β-L-rhamnopyranoside	53-54	+106 (c 1, H ₂ O)
370	D-Mannose benzylphenylhydrazide			398	2, 4, 6-Tri-O-methyl-α-D-mannose monohydrate	89-90	+23 → +16 (c 1, H ₂ O)	429	2, 3, 4-Tri-O-methyl-L-rhamnose	Sirup	+26 (c 2.5, H ₂ O)
				399	2, 4, 6-Tri-O-methyl-β-D-mannose monohydrate	104-107	-5.7 → +19 (c 2.1, H ₂ O)	430	2, 3, 4-Tri-O-methyl-L-rhamnose anilide	112	+127
				400	3, 4, 6-Tri-O-methyl-α-D-mannopyranose	101-102	+21 → +8.2 (c 1, H ₂ O)	431	L-Talose, 6-deoxy- (L-talomethylolose) (C ₆ H ₁₂ O ₅)	116-118	-19.5±2 [18°]
				401	Methyl tetra-O-methyl-α-D-mannopyranoside	39-40	+43.5 (c 5, H ₂ O)				

371	D-Mannose p-bromophenylhydrazine	208		402	Tetra-O-methyl-α-D-mannopyranose	50-51	+7.4 \rightarrow +2.4 (H ₂ O)	432	L-Talomethylose p-bromophenylhydrazine	145-147	-10 \rightarrow +4 \pm 3 [16°] (c 0.8, C ₂ H ₅ OH)
372	D-Mannose p-nitro phenylhydrazine	194-195, 202-203	+56 (C ₅ H ₅ N, C ₂ H ₅ OH)	403	Methyl tetra-O-methyl-β-D-mannopyranoside	37	-80 (c 1, H ₂ O)	433	L-Talonic acid lactone	134-135	+36 \rightarrow +33 \pm 2 (c 1, H ₂ O)

/1/ Includes substances not found free but found in the hydrolyzates of a natural material. Unless otherwise stated, all data are for crystalline substances. /2/ In preparing this table the literature has been covered through 1952. /3/ Aldoses are arranged alphabetically within groups formulated according to increasing carbon content in the parent sugar. Since the substances are listed by their accepted chemical nomenclature, or derivative thereof, the following list of common or trivial names or synonyms is given, with relationship to listing in the table, to facilitate location of a substance: apiose (see D-glyceraldehyde), chinovose (see D-glucose), chitosamine (see D-glucose), chondrosamine (see D-galactose), cymarose (see D-allose), diginose (see D-galactose), digitalose (see D-galactose), digitoxose (see D-allose), epirhamnose (see D-glucose), D-fucose (see D-galactose), L-fucose (see L-galactose), galactosamine (see D-galactose), glucosamine (see D-glucose), hamamelose (see D-Ribose), isorhamnose (see D-glucose), isorhodoose (see D-glucose), oleandrose (see L-glucose), quinovose (see D-glucose), L-rhamnose (see L-mannose), sarmentose (see D-glucose), streptose (see L-lyxose), thevetose (see D- and L-glucose), vaccinin (see D-glucose). /4/ Unless otherwise stated, the specific rotations are taken in water at concentrations of 5 g or less per 100 ml of solution and at 20-25°C. Other temperatures or wave lengths are shown in brackets. c = g solute per 100 ml solution. /5/ The rotation given is taken from inference to the enantiomorph or D isomer. /6/ The designations for the α and β pair of these compounds are reversed from those of the original authors, in accordance with modern terminology and Hudson's rules of rotation. /7/ Since the esters and ethers of L-Lyxose are unknown the derivatives of unnatural D-Lyxose are given for reference. /8/ Some question exists on the presence of this material in nature. /9/ This substance is included because of the speculations concerning it in biological processes. /10/ This structure for sarmentose is postulated but not proved in reference. /11/ Passes through a minimum in mutarotating.

Part II: NATURAL MONOSACCHARIDES: KETOSES^{1,2}

Substance ³	MP °C	[α] _D , degrees ⁴	Substance ³	MP °C	[α] _D , degrees ⁴	Substance ³	MP °C	[α] _D , degrees ⁴
1 Triulose (dihydroxyacetone) (C ₃ H ₆ O ₃)	80 (dimer)	None	25 β -D-Arabo-hexulose (β -D-fructose) (levulose) (C ₆ H ₁₂ O ₆) (concluded)	Sirup	-87.5 (c 0.4, H ₂ O)	45 D-Ribo-hexulose (D-psicose) (C ₆ H ₁₂ O ₆)	Amorp.	+4.7
2 Dihydroxyacetone p-nitro phenylhydrazine	160		26 4-O-Methyl-D-fructose	Sirup	+6.4 (c 1.2, 0.06N HCl)	46 Penta-O-acetyl-keto-D-psicose	63-65	-21.5 [29°] (c 3, CHCl ₃)
3 Dihydroxyacetone oxime	84		27 3,4-Di-O-methyl-D-fructose	Sirup	-60.7 (c 0.8, H ₂ O)	47 Methyl tetra-O-methyl-D-psicopyranoside	Sirup	+36 heated in (HCl, CH ₃ OH)
4 Dihydroxyacetone bis(2,4-dinitrophenylhydrazine)			28 Methyl 1,3,4-tri-O-methyl-D-fructoside	Sirup	+57.4 (c 1, H ₂ O)	48 Di-O-isopropylidene-D-psicose	57-58.5	-98.2 (c 2, CH ₃ COCH ₃)
5 Dihydroxyacetone diacetate	46-47		29 1,3,4-Tri-O-methyl-D-fructose	73	-23.8 \rightarrow -51.8 (c 8, H ₂ O)	49 L-Xylo-hexulose (L-sorbose) (C ₆ H ₁₂ O ₆)	159-161	-43.1
6 L-Glycero-tetralose ⁵ (L-erythrulose) (ketotriitol) (L-threulose) (C ₄ H ₈ O ₄)	Sirup	+12	30 1,4,6-Tri-O-methyl-D-fructose	Sirup	+30.3 (H ₂ O)	50 Di-O-isopropylidene-L-sorbose	155-157	+44.9 (c 1, CH ₃ COCH ₃)
7 L-Erythrulose, O-nitro-phenylhydrazine	152-153	+48 [18°] (c 1, C ₂ H ₅ OH)	31 3,4,5-Tri-O-methyl-D-fructose	Sirup	-115.9 (H ₂ O)	51 Penta-O-acetyl-keto-L-sorbose	99	+2.4 [578] (CHCl ₃)
8 D-Erythro-pentulose (adonose) (D-ribulose) (C ₅ H ₁₀ O ₅)	Sirup	+16.6 [27°]	32 3,4,6-Tri-O-methyl-D-fructose	Sirup	+20.4, +26.6 [15°] (c 1, CHCl ₃)	52 Tetra-O-acetyl-L-sorbo-pyranose	100.8	-21.3 (c 1.3, CHCl ₃)
9 1,3,4,5-Di-O-iso-propylidene-D-ribulose (diacetone ribulose)	5	+105.5 [27°] (c 1, CH ₃ COCH ₃)	33 Methyl 1,3,4,5-tetra-O-methyl- β -D-fructopyranoside	33-34	-149.8 (c 3, H ₂ O)	53 Penta-O-acetyl- α -L-sorbo-pyranose	97	-56.5 (c 1.3, CHCl ₃)
10 L-Threo-pentulose (L-xylose) (L-lyxulose) (xyloketo) (C ₅ H ₁₀ O ₅)	Sirup	+33.1	34 1,3,4,5-Tetra-O-methyl-D-fructose	98-99	-124.7 \rightarrow -121.3 (c 5, H ₂ O)	54 Penta-O-acetyl- β -L-sorbo-pyranose	113.8	+74.4 (c 1.3, CHCl ₃)
11 L-Xylulose p-bromophenylhydrazine	128-129	-26 \rightarrow +31.9 (C ₅ H ₅ N)	35 Methyl 1,3,4,6-tetra-O-methyl- α -D-fructofuranoside	Sirup	+129.4 (c 2.6, H ₂ O)	55 Methyl tetra-O-methyl-L-sorbofuranoside	Sirup	-39.4 (c 1, CHCl ₃)
12 β -D-Arabo-hexulose (β -D-fructose) (levulose) (C ₆ H ₁₂ O ₆)	102-104	-133.5 \rightarrow -92	36 1,3,4,6-Tetra-O-methyl-D-fructose	Sirup	+31.3 [16°] (c 2, H ₂ O)	56 Tetra-O-methyl-L-sorbo-furanose	Sirup	+29.7 (c 1, CHCl ₃)
13 D-Fructose p-nitro phenylhydrazine	176		37 1,3,4,6-Tetra-O-methyl-D-fructofuranamide	99-100	-76 [16°] (c 1, H ₂ O)	57 Methyl α -L-sorbo-pyranoside	120-122	-88.9 (c 8, H ₂ O)
14 D-Fructose oxime	118		38 D-Lyxohexulose (D-tagatose) (C ₆ H ₁₂ O ₆)	131-132	+2.7 \rightarrow -4, -5	58 Methyl β -L-sorbo-pyranoside	106.2	+39 (c 1.7, H ₂ O)
15 1,3,4,5-Tetra-O-acetyl- β -D-fructopyranose	131-132	-91.6 (c 3, CHCl ₃)	39 "Tagaturonic" acid	106-108	-12.5 (c 1.6, H ₂ O)	59 1,4,6-Tri-O-methyl-L-sorbofuranose	Sirup	+3.8 (c 1.5, CHCl ₃)
16 1,3,4,5,6-Penta-O-acetyl-D-fructose	70	+34.7 (c 8, CHCl ₃)	40 Penta-O-acetyl-D-tagatopyranose	132	+30.2 [578] (c 4, CHCl ₃)	60 Methyl tetra-O-methyl- α -L-sorbo-pyranoside	Sirup	-46.2 [578] (c 2, CHCl ₃)
17 Penta-O-acetyl- β -D-fructopyranose	108-109	-120.9 (c 5, CHCl ₃)	41 Methyl α -D-tagatopyranose	128	+56.8 [578] (c 2, CH ₃ OH)	61 Methyl tetra-O-methyl- β -L-sorbo-pyranoside	Sirup	+69.8 (c 1, CHCl ₃)
18 Methyl α -D-fructofuranoside	69, 81	+93 (c 2, H ₂ O)	42 Methyl tetra-O-methyl- α -D-tagatopyranoside	Sirup	+21.4 [578] (c 2, CH ₃ OH)	62 1,3,4,5-Tetra-O-methyl-L-sorbose	Sirup	-15.1 [578] (c 2, CHCl ₃)
19 Methyl β -D-fructofuranoside	Sirup	-50 (c 1, H ₂ O)	43 Methyl tetra-O-methyl-D-tagatose	Sirup	+9.7 [578] (c 2, CH ₃ OH)	63 4-O-Methyl-L-sorbose	133	-30.9 [12°] (c 2, H ₂ O)
20 Methyl α -D-fructopyranoside	96-97	+44 (c 1, H ₂ O)	44 Tetra-O-methyl-D-tagatopyranose	Sirup	-3.4 [578] (c 2, CH ₃ OH)	64 D-Altro-heptulose (D-sedoheptulose) (sedoheptose) (C ₇ H ₁₄ O ₇)	Amorph.	+2.5 (c 10)
21 Methyl β -D-fructopyranoside	119-120	-172.1 (c 10, H ₂ O)				65 α -Sedoheptitol (volemitol) (D-glycero-D-manno-heptitol) (D-manno-D-taloheptitol) (D-altro-D-mannoheptitol)	152	+2.3 (c 9, H ₂ O)
22 1-O-Methyl-D-fructose	Sirup	-49.8 (c 2.2, CH ₃ OH)						
23 Methyl 3-O-methyl-D-fructoside	143	-34.6 (c 1.1, C ₂ H ₅ OH)						
24 3-O-Methyl-D-fructose	122-123	-70.5 \rightarrow -53.1 (H ₂ O)						

9. CARBOHYDRATES: PHYSICAL AND CHEMICAL CHARACTERISTICS (Continued)

Part II: NATURAL MONOSACCHARIDES: KETOSES^{1,2} (Concluded)

Substance ³	MP °C	[α] _D , degrees ⁴	Substance ³	MP °C	[α] _D , degrees ⁴	Substance ³	MP °C	[α] _D , degrees ⁴
66 D-Altro-heptulose (D-sedoheptulose) (C ₇ H ₁₄ O ₇) (concluded)			69 D-Perseitol (D-manno-D-galaheptitol, α-mannoheptitol, D-glycero-D-galaheptitol)	187	-1.2 (c 5.5, H ₂ O)	73 D-Manno-heptulose (mannoketoheptose) (D-manno-D-tagatose) (C ₇ H ₁₄ O ₇)	152	+29.4
β-Sedoheptitol (D-glycero-D-glucoseheptitol) (L-gulo-D-taloheptitol) (D-alto-D-glucoseheptitol)	127-128		70 L-Gala-D-glucoseheptitol (L-glycero-D-galaheptitol, L-glycero-D-glucoseheptitol)	141	-2.4 (c 4, H ₂ O)	74 D-Manno-heptulose p-bromophenylhydrazide	179	
67 Sedoheptulosan	155	-146 (c 9, H ₂ O)	71 Hexa-O-acetyl-keto-L-perseulose	105	+0.57 [578] (c 4, CHCl ₃)	D-Perseitol and volemitol (See Lines 69 and 65 above)		
68 L-Gala-heptulose hemihydrate (L-perseulose) (C ₇ H ₁₄ O ₇ · ½ H ₂ O)	110-115	-90 → -80	72 Hexa-O-acetyl-L-perseulose	112	-113 [578] (c 1, CHCl ₃)	75 D-Manno-heptulose hexaacetate	110	+39 (c 2, CHCl ₃)

/1/ Includes substances not found free but found in the hydrolyzates of a natural material. Also included are some substances which are bacterial oxidation products of a natural material. Unless otherwise stated, all data are for crystalline substances. /2/ In preparing this table the literature has been covered through 1952. /3/ Ketoses are arranged alphabetically within groups formulated according to increasing carbon content in the parent sugar. Since the substances are listed under their systematic name in carbohydrate nomenclature the following list of common names and synonyms is given to facilitate the location: adonose (see D-erythro-pentulose), D-allulose (see D-ribo-hexulose), dihydroxyacetone (see triulose), L-erythrulose (see D-glycero-tetrolulose), D-fructose (see D-arabo-hexulose), levulose (see D-arabo-hexulose), L-lyxulose (see L-threo-pentulose), perseulose (see L-gala-heptulose), D-psicose (see D-ribo-hexulose), D-ribulose (see D-erythro-pentulose), D-sedoheptulose (see D-alto-heptulose), L-sorbose (see L-xylo-hexulose), D-tagatose (see L-xylo-hexulose), L-threulose (see L-glycero-tetrolulose), volemose (see D-alto-heptulose), L-xyulose (see L-threo-pentulose), xyloketo (see L-threo-pentulose). /4/ Unless otherwise stated, the specific rotations are taken in water at concentrations of 5 g or less per 100 ml of solution and at 20-25°C. Other temperatures or wave lengths are shown in brackets; c = g solute per 100 ml of solution. /5/ Some of the early literature names this substance D-erythrulose.

Part III: NATURAL OLIGOSACCHARIDES^{1,2}

Substance ³	MP °C	[α] _D , degrees ⁴	Substance ³	MP °C	[α] _D , degrees ⁴	Substance ³	MP °C	[α] _D , degrees ⁴
1 O-α-D-Manno-pyranosyl-L-glyceric acid (C ₉ H ₁₆ O ₉)	88-89	+105 [15°]	37 β-Maltose monohydrate (C ₁₂ H ₂₂ O ₁₁ · H ₂ O)	102-103	+112.5 → +130	69 O-D-Mannopyranosyl-(1 → 6)-O-D-mannopyranosyl-	217	-16, -15.3, -11.6
2 Sodium salt	270 d.		38 β-Maltose octaacetate	159-160	+62.6 (c 5, CHCl ₃)	(1 → 6)-O-D-glucopyranose (levulinose?) (C ₁₈ H ₃₂ O ₁₆)		
3 2-O-α-D-Galactopyranosyl-glycerol (C ₉ H ₁₈ O ₈)	86-87	+151	39 4-O-β-D-Manno pyranosyl-β-D-mannopyranose (C ₁₂ H ₂₂ O ₁₁)	193-194	-7.7 → -2.2	70 6-[6-(Mannopyranosyl)-mannopyranosyl]-glucopyranose hendecaacetate	95-110	+18
4 Galactinol dihydrate (1-O-α-D-galactopyranosyl-myo-inositol dihydrate) (C ₁₂ H ₂₂ O ₁₁ · 2H ₂ O)	220-222	+135.6	40 β-Melibiose dihydrate (6-O-α-D-galactopyranosyl-β-D-glucopyranose) (C ₁₂ H ₂₂ O ₁₁ · 2H ₂ O)	82-85	+111.7 → +129.5	71 Melezitose dihydrate (O-α-D-glucopyranosyl-(1 → 3)-O-β-D-fructofuranosyl-(2 → 1)-α-D-glucopyranoside) (C ₁₈ H ₃₂ O ₁₆ · 2H ₂ O)	153-154	+88.2
5 Galactinol nonamethyl ether	96.5-98	+119 (c 2, H ₂ O)	41 β-Melibiose octaacetate	177	+102.5	72 Melezitose hendecaacetate	117	+103.6 (c 1, CHCl ₃)
6 Primverose (6-O-β-D-xylopyranosyl-D-glucose) (C ₁₁ H ₂₀ O ₁₁)	208	+24.1 → -3.3	42 Robinobiose (6-O-β-L-rhamnopyranosyl-D-galactopyranose) (C ₁₂ H ₂₂ O ₁₀)	Amorph.	+2.72 → 0	73 Planteose dihydrate (O-α-D-galactopyranosyl-(1 → 6)-O-β-D-fructofuranosyl-(1 → 6)-O-α-D-glucopyranoside) (C ₁₈ H ₃₂ O ₁₆ · 2H ₂ O)	123-124	+125.2
7 Primverose heptaacetate	216	-23.5 (CHCl ₃)	43 Robinobiose heptaacetate	113, 84-85	-19.23, -9.9 (CHCl ₃)	74 Planteose hendecaacetate	135	+97 (c 1, CHCl ₃)
8 Vicianose (6-O-α-L-arabinopyranosyl-D-glucose) (C ₁₁ H ₂₀ O ₁₀)	210	+56.6 → +40.3 [14°]	44 Methyl β-robinobioside hexaacetate	159-160	-39.6 (CHCl ₃)	75 Raffinose pentahydrate (O-α-D-galactopyranosyl-(1 → 6)-O-α-D-glucopyranosyl-(1 → 2)-O-β-D-fructofuranoside) (C ₁₈ H ₃₂ O ₁₆ · 5H ₂ O)	80, 118-120	+105, +123.1
9 Vicianose heptaacetate	158-160	+6.5 [14°] (CHCl ₃)	45 Rutinose (6-O-β-L-rhamnopyranosyl-D-glucopyranose) (C ₁₂ H ₂₂ O ₁₀)	189-192 d. amorph.	+3.2 → -0.8 [10°]	76 Raffinose hendecaacetate	99-101	+92.2, +100.3 (c 8, C ₂ H ₅ OH)
10 D-Xylopyranosyl D-glucopyranoside ⁵ (C ₁₁ H ₂₀ O ₁₀)	Amorph.	-36.5	46 Rutinose heptaacetate	168-169	-29.7 (CHCl ₃)	77 Rhamninose (C ₁₈ H ₃₂ O ₁₄)	135-140 d.	-41.0
11 D-Xylopyranosyl D-glucopyranoside dibenzoate	147-148	-106.7 (c 2, CH ₃ OH)	47 Scillabiose (4-O-D-glucopyranosyl-L-rhamnopyranose) (C ₁₂ H ₂₂ O ₁₀)	Amorph.	-24.8	78 Rhamninose octaacetate (?)	95-100	-30.9 (C ₂ H ₅ OH)
12 D-Xylopyranosyl D-glucopyranoside pentaacetate dibenzoate	203		48 Scillabiose hexaacetate	97		79 Robinose ⁷ (C ₁₈ H ₃₂ O ₁₄) amorph.		+5.2 → +1.9
13 iso-D-Xylosyl-D-glucoside dibenzoate	173-174	-6.3 (c 0.8, CH ₃ OH)	49 α-Sophorose monohydrate (2-O-β-D-glucopyranosyl-α-D-glucopyranose) (C ₁₂ H ₂₂ O ₁₁ · H ₂ O)	195-196	+32 → +18	80 Scordose (C ₂₄ H ₄₂ O ₂₁) amorph.	200	-41.5
14 Allolactose (6-O-β-D-galactopyranosyl-D-glucose) (C ₁₂ H ₂₂ O ₁₁)	165	+25	50 α-Sophorose octaacetate	111	+45 (c 1, CHCl ₃)	81 Acetyl scordose	85-90	-28.5 (c 5.4, CHCl ₃)
15 Allolactose octaacetate	166		51 β-Sophorose octaacetate	192	-2.8 (c 10, CHCl ₃)			
16 Amylolyose (3-O-β-D-glucopyranosyl-D-glucose) (C ₁₂ H ₂₂ O ₁₁)		+59.3 → +46.4 [15°] (CH ₃ OH)	52 Sucrose (β-D-fructofuranosyl-α-D-glucopyranoside) (C ₁₂ H ₂₂ O ₁₁)	188, 170 ⁶	+66.5 (c 26)			
17 β-Cellobiose (4-O-β-D-glucopyranosyl-β-D-glucopyranose) (C ₁₂ H ₂₂ O ₁₁)	225	+14.2 → +34.6 (c 8)						

18	α -Cellobiose octaacetate	229	+41.0 (c 6, CHCl ₃)	53	Sucrose octaacetate	69, 75 ⁶	+59.6 (CHCl ₃)	82	Stachyose (manneotetrose) (O- α -D-galactopyranosyl-(1 \rightarrow 6)-O- α -D-galactopyranosyl-(1 \rightarrow 6)-O- α -D-galactopyranosyl-(1 \rightarrow 2)-O- β -D-fructofuranoside) (C ₂₄ H ₄₂ O ₂₁)	170 (140 s.)	+146.3
19	β -Cellobiose octaacetate	202	-14.7 (c 5, CHCl ₃)	54	Trehalose dihydrate (C ₁₂ H ₂₂ O ₁₁ ·2H ₂ O)	97	+178.3 (c 7)				
20	α -Gentiobiose (C ₁₂ H ₂₂ O ₁₁ ·2CH ₃ OH)	85-86	+31 \rightarrow +9.6	55	Trehalose (α -D-glucopyranosyl- α -D-glucopyranoside) (C ₁₂ H ₂₂ O ₁₁)	203		83	Stachyose tetradecaacetate	95-96 amorph.	+120.2 (C ₂ H ₅ OH)
21	α -Gentiobiose octaacetate	189	+52.4 (c 4, CHCl ₃)	56	Trehalose octaacetate	98	+162.3 (c 10, CHCl ₃)				
22	β -Gentiobiose (6-O- β -D-glucopyranosyl- β -D-glucopyranose) (C ₁₂ H ₂₂ O ₁₁)	190	-3.0 \rightarrow +10.5	57	Turanose (3-O- α -D-glucopyranosyl-D-fructopyranose) (C ₁₂ H ₂₂ O ₁₁)	157	+22 \rightarrow +75.3	84	Verbascose (O- α -D-galactopyranosyl-(1 \rightarrow 6)-O- α -D-galactopyranosyl-(1 \rightarrow 6)-O- α -D-galactopyranosyl-(1 \rightarrow 2)-O- β -D-fructofuranoside) (C ₃₀ H ₅₂ O ₂₆)	219-220, 253	+169.9
23	β -Gentiobiose octaacetate	193	-5.4 (c 6, CHCl ₃)	58	Turanose octaacetate, I	216-217	+20.5 (c 4, CHCl ₃)				
24	Gynolactose (C ₁₂ H ₂₂ O ₁₁)	205	-27	59	Turanose octaacetate, II	158	+107 (c 1, CHCl ₃)	85	Verbascose heptadecaacetate	132	+130.4
25	Isomaltose (6-O- α -D-glucopyranosyl- β -D-glucopyranose) (C ₁₂ H ₂₂ O ₁₁)	Amorph.	+103.2, +122	60	Turanose octaacetate, III (keto form)	96	+126.2 (c 6, CHCl ₃)	86	Hexasaccharide (cyclic oligosaccharide) (C ₃₆ H ₆₀ O ₃₀ ·12H ₂ O)	290-300	+151.8
26	β -Isomaltose octaacetate	144-145	+96.9 (c 2.7, CHCl ₃)	61	Turanose octaacetate, IV	194-195	+103.2 (c 3, CHCl ₃)	87	Octadeca-O-Methyl-hexasaccharide (cyclic)	98-103	+160.5
27	α -Lactose monohydrate (C ₁₂ H ₂₂ O ₁₁ ·H ₂ O)	202	+83.5 \rightarrow +52.6	62	Gentianose (O- β -D-glucopyranosyl-(1 \rightarrow 6)-O- α -D-glucopyranosyl-(1 \rightarrow 2)- β -D-fructofuranoside) (C ₁₈ H ₃₂ O ₁₆)	210	+33.4	88	Schardinger- α -dextrin (cyclohexamylose) (C ₃₆ H ₆₀ O ₃₀)		+150.6
28	α -Lactose octaacetate	152	+53.6 (c 10, CHCl ₃)	63	Labiose trihydrate (C ₁₈ H ₃₂ O ₁₆ ·3H ₂ O)	BP 205 (126 s.)	+136.7	89	α -Dextrin acetate		+105.5 (c 1, CHCl ₃)
29	β -Lactose (4-O- β -D-galactopyranosyl- β -D-glucopyranose) (C ₁₂ H ₂₂ O ₁₁)	252	+34.2 \rightarrow +53.6	64	Labiose hendecaacetate	88	+122.5 (CHCl ₃)	90	Schardinger- β -dextrin (cycloheptaamylose) (C ₄₂ H ₆₈ O ₃₄)		+162.5
30	β -Lactose octaacetate	90	-4.7 (c 10, CHCl ₃)	65	Maltotriose (O- α -D-glucopyranosyl-(1 \rightarrow 4)-O- α -D-glucopyranosyl-(1 \rightarrow 4)-O- β -D-glucopyranose) (C ₁₈ H ₃₂ O ₁₆)	150 amorph.	+160	91	β -Dextrin acetate	196-196.5	+125.5
31	Laminaribiose (3-O- β -D-glucopyranosyl- β -D-glucopyranose) (C ₁₂ H ₂₂ O ₁₁)	160-163	+20.8 \rightarrow +16.1, +23.4 \rightarrow +19	66	β -Maltotriose hendecaacetate	134-136	+86 (c 1.6, CHCl ₃)	92	Schardinger- γ -dextrin (cyclooctaamylose) (C ₄₈ H ₇₆ O ₃₈)		+177.4
32	α -Laminaribiose octaacetate monoethanolate	188-192	+7.5 \rightarrow +20.8	67	Manninotriose (O- α -D-galactopyranosyl-(1 \rightarrow 6)-O- α -D-galactopyranosyl-(1 \rightarrow 6)- α -D-glucopyranose) (C ₁₈ H ₃₂ O ₁₆)	Amorph.	+167	93	γ -Dextrin acetate		+138.5 (c 1, CHCl ₃)
33	β -Laminaribiose octaacetate	77-78	+20 (c 3.6, CHCl ₃)	68	Manninotriose hendecaacetate	(105 s.)	+135 (C ₂ H ₅ OH)				
34	β -Laminaribiose octaacetate	160-161	-28.8 (c 2.5, CHCl ₃)								
35	α -Maltose (4-O- α -D-glucopyranosyl- α -D-glucopyranose) (C ₁₂ H ₂₂ O ₁₁)	108	+173								
36	α -Maltose octaacetate	125	+122.8 (c 5, CHCl ₃)								

/1/ This table is limited to those oligosaccharides which exist free, or as simple derivatives, in nature or which may be derived from a larger oligosaccharide or a polysaccharide by means of enzymic action. /2/ In preparing this table the literature has been covered through 1952, and partially through 1953. Unless otherwise noted, all data are for crystalline materials. /3/ The substances are arranged alphabetically within groups which are formulated according to increasing carbon content. /4/ Unless otherwise stated, the rotations are taken in water at concentrations less than 5 and at temperatures of 20-25°C. Other temperatures are shown in brackets; c = grams solute per 100 ml of solution. /5/ The free sugar does not exist in nature but the dibenzoyl derivatives do. /6/ The compound crystallizes in one of two forms, depending on the solvent used. /7/ This substance may be robinobiose.

Part IV: NATURAL ALDITOLS AND INOSITOLS¹

Substance ²	MP °C	[α] _D , degrees ³	Substance ²	MP °C	[α] _D , degrees ³	Substance ²	MP °C	[α] _D , degrees ³
1 Glycerol (C ₃ H ₈ O ₃)	20	None	11 D-Threitol, 1,4-dideoxy-(C ₄ H ₁₀ O ₂)	19	-13.0	18 D-Arabitol (C ₆ H ₁₂ O ₅) (concluded)		
2 Glycerol tribenzoate	76	None	12 1,4-Dideoxy-D-threitol diacetate	Sirup BP 192-194/745 mm	+1.4	19 D-Arabitol pentaacetate	76	+37.2 (CHCl ₃)
3 Glycerol, α -deoxy- (1,2-propanediol) ⁴ (C ₃ H ₈ O ₂)	Oil, BP 188-189	(Racemic) none	13 L-Threitol, 1,4-dideoxy-(C ₄ H ₁₀ O ₂)		+10.2	20 Ribitol (adonitol) (C ₅ H ₁₂ O ₅)	102	(Meso), none
4 1,2-Propanediol distearate	72-73	None	14 D,L-Threitol, 1,4-dideoxy-(C ₄ H ₁₀ O ₂)	7.6	None	21 Ribitol pentaacetate	51	
5 Erythritol (C ₄ H ₁₀ O ₄)	118-120	(Meso), none	15 1,4-Dideoxy-D,L-threitol diacetate	41-41.5		22 Galactitol (dulcitol) (C ₆ H ₁₄ O ₆)	186-188	(Meso), none
6 Erythritol tetraacetate	85	None	16 1,4-Dideoxy-D,L-threitol dibenzoate	53-54		23 Galactitol hexaacetate	168-169	
7 Erythritol, 1,4-dideoxy- (2,3-butyleneglycol)(C ₄ H ₁₀ O ₂)	25, 34	(Meso), none	17 D-Arabitol (C ₅ H ₁₂ O ₅)	103	+7.82 (c 8, borax soln.)	24 L-Iditol (C ₆ H ₁₄ O ₆)	73.5	-3.5 (c 10)
8 1,4-Dideoxy-erythritol penta-hydrate	16.8					25 L-Iditol hexaacetate	121.5	-25.7 (c 5, CHCl ₃)
9 2,3-Butyleneglycol diphenyl-urethane	196					26 D-Mannitol (C ₆ H ₁₄ O ₆)	166	-0.21
10 2,3-Butyleneglycol dibenzoate	77					27 D-Mannitol hexaacetate	126	+18.8 (CH ₃ COOH)
						28 D-Mannitol, 1,5-anhydro-(styracitol) (C ₆ H ₁₂ O ₅)	157	-49.9
						Styracitol tetraacetate	66-67	-20.9 (C ₂ H ₅ OH)

9. CARBOHYDRATES: PHYSICAL AND CHEMICAL CHARACTERISTICS (Continued)

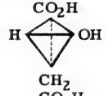
Part IV: NATURAL ALDITOLS AND INOSITOLS (Concluded)

Substance ³	MP °C	[α] _D , degrees ⁴	Substance ³	MP °C	[α] _D , degrees ⁴	Substance ³	MP °C	[α] _D , degrees ⁴
29 Sorbitol (D-glucitol) (C ₆ H ₁₄ O ₆)	112	-1.8 [15°]	46 Dambonitol (meso-inositol di- methyl ether) (C ₈ H ₁₆ O ₆)	206	None	66 D-Quercitol pentaacetate		
30 Sorbitol hexaacetate	99	+12.5 (c 0.8, CHCl ₃)	47 Dambonitol tetraacetate	195		67 L-Quercitol (deoxy-L- inositol) ⁸ (C ₆ H ₁₂ O ₅)	174	-73.9
31 Sorbitol, 1,5-anhydro- (polygalitol) (C ₆ H ₁₂ O ₅)	140-141	+42.4	48 meso-Inositol (myo-inositol) (C ₆ H ₁₂ O ₆)	217-218	None	68 L-Quercitol pentaacetate	124-125	-26.0 (c 2.7, CHCl ₃)
32 Polygalitol tetraacetate	73-74	+38.9 (c 2, CHCl ₃)	49 meso-Inositol hexaacetate	211-212		69 D-Quinic acid (2,3,4-tri- deoxy-3-carboxy-D- inositol) (C ₇ H ₁₂ O ₆)	164	+44 (c 10)
33 D-Perseitol (D-manno-D-gala- heptitol)(D-gala-D-glycero- heptitol) (C ₇ H ₁₆ O ₇)	188	-1.1	50 meso-Inositol monophosphate	190-191 d.		70 L-Quinic acid (C ₇ H ₁₂ O ₆)	162	-42.1
34 D-Perseitol heptaacetate	119	-13.3 (CHCl ₃)	51 meso-Inositol monophosphate brucine salt ⁵	236-238		71 L-Quinic acid lactone tri- acetate (form 1)	132	
35 D-Volemitol (D-manno-D-talo- heptitol)(D-talo-D-glycero- heptitol) (C ₇ H ₁₆ O ₇)	153	+2.65	52 meso-Inositol hexaphosphate dodeca-sodium salt +38 H ₂ O ⁶	58-59		72 L-Quinic acid lactone tri- acetate (form 2)	139	
36 D-Volemitol heptaacetate	62	+36.1 (c 2, CHCl ₃)	53 meso-Inositol tetrakisphosphate ⁷		-3.9 (H ₂ O) [14.5°] -8.3 (H ₂ O) [15°] -6.0 (H ₂ O)	73 L-Quinic acid tetraacetate	130-136	-22.5 (c 5, C ₂ H ₅ OH)
37 Betitol (a dideoxy inositol) (C ₆ H ₁₂ O ₄)	224		54 meso-Inositol tri- phosphate ⁷			74 D-Quinic acid		
38 Bioinosose (scyllo-meso-inosose) (inosose) (C ₆ H ₁₀ O ₆)	198-200		55 meso-Inositol diphosphate ⁷			75 Scyllitol (cocositol) (C ₆ H ₁₂ O ₆)	352-353	None
39 Inosose phenylhydrazine	220-222		56 D-Inositol (C ₆ H ₁₂ O ₆)	253		76 Scyllitol hexaacetate	299-300	None
40 Inosose pentaacetate	106-108		57 D-Inositol hexaacetate	111		77 Streptidine (1,3-dideoxy-1,3- diguandino-scyllitol) (C ₈ H ₁₈ N ₆ O ₄)		None
41 Bornesitol (meso-inositol mono- methyl ether) (C ₇ H ₁₄ O ₆)	200	+31.6	58 Mytilitol (c-methyl-scyllitol) (C ₇ H ₁₄ O ₆)	259	(Meso), none	78 Di-N-acetyl-tetra-O-acetyl- streptamine	342-345	None
42 Conduritol (2,3-dehydro-2,3-di- deoxy-D-inositol) (C ₆ H ₁₀ O ₄)	142-143	None	59 Mytilitol pentaacetate	157-158		79 N,N'-Diacetyl-streptamine	383-384	None
43 Conduritol dibromide	176		60 Mytilitol hexaacetate	180-181		80 Streptamine hemihydrate (1, 3-diamino-1,3-dideoxy scyllitol)	205 a.	None
44 Conduritol tetraacetate	BP 165° at 0.6 mm		61 Pinilitol (D-inositol mono- methyl ether) (C ₇ H ₁₄ O ₆)	186	+65.5	81 Streptidine dipicrate	284-285 d.	None
45 Dihydroconduritol	204		62 Pinilitol pentaacetate	98	+8.6 (c 2, C ₂ H ₅ OH)	82 Sequoyitol (meso-inositol mono- methyl ether) (C ₇ H ₁₄ O ₆)	234-235	(Meso), none
			63 Quebrachitol (L-inositol monomethyl ether) (C ₇ H ₁₄ O ₆)	190-191	-80.2 [28°]	83 Sequoyitol pentaacetate	198	
			64 Quebrachitol pentaacetate	96-97	-25.1 [29°] (c 4, CHCl ₃)	84 Shikimic acid (3,4-dehydro- quimic acid) (C ₇ H ₁₀ O ₅)	183-184	-200 [16°]
			65 D-Quercitol (deoxy-D- inositol) (C ₆ H ₁₂ O ₅)	235	+24.2	85 Methyl shikimate	113-114	
						86 Shikimic acid triacetate	Sirup BP 0.1 200-210	

1/ This table contains the alditols and inositols which occur in nature, free or as hydrolytic products from natural substances. Naturally occurring simple derivatives of these polyols are also included. The literature has been covered through 1952 and partially through 1953. Unless otherwise noted all data are for crystalline materials. 2/ The alditols are all listed first, arranged alphabetically in groups which are formulated according to increasing carbon content in the parent compound. The inositols are then listed similarly. 3/ Unless otherwise stated the rotations are taken in water at concentrations less than 5 and at temperatures of 20-25°C. Other temperatures are shown in brackets; c = grams solute per 100 ml of solution. 4/ The 1-phosphate ester of this diol is said to occur in brain tissue and sea urchin eggs. 5/ Found as a hydrolyzate product of lipositol. 6/ Prepared from natural phytin, the calcium and magnesium salt of phytic acid or meso-inositol hexaphosphate. 7/ Obtained by enzyme action on meso-inositol hexaphosphate. 8/ This is not an enantiomorph of D-quercitol. Other isomeric relationship is involved.

Part V: NATURAL ALDONIC, URONIC, AND ALDARIC ACIDS¹

Substance ²	MP °C	[α] _D , degrees ³	Substance ²	MP °C	[α] _D , degrees ³	Substance ²	MP °C	[α] _D , degrees ³
1 D-Glyceric acid (C ₃ H ₆ O ₄)	Gum	Dextro	39 D-Gluconic acid, 2-deoxy-2- "keto"- (C ₆ H ₁₀ O ₇) (concluded)	168-169	-133 (c 2, CHCl ₃)	70 β-D-Glucuronic acid (C ₆ H ₁₀ O ₇) (concluded)		
2 Methyl D-glycerate	Sirup BP 119/14 mm	-4.8	40 D-Gluconic acid ⁵ , 5-deoxy-5- "keto"- (C ₆ H ₁₀ O ₇)		-14.5	71 Methyl (methyl 4-O-methyl- D-glucopyranoside)	Sirup	95 (c 10, H ₂ O)
3 Methyl 2,3-di-O-methyl-D- glycerate	Sirup BP | -69.7 77/15 mm	-63.1 (c 2.4, CH ₃ OH)	41 5-Deoxy-5-"keto"-D-gluconic acid phenyllosazone	110-130	variable	72 Methyl 4-O-methyl-α-D-glu- copyranosiduronamide	236	150
4 D-Glyceronamide	99.5-100	-54.5 (c 3.1, CH ₃ OH)	42 5-Deoxy-5-"keto"-D-gluconic acid p-nitrophenylhydrazine	190-212	variable	73 Methyl 4-O-methyl-β-D-glu- copyranosiduronamide	232	-50
5 2,3-Di-O-methyl-D- glyceronamide	77-77.5	-33.2	43 D-Mannonic acid (C ₆ H ₁₂ O ₇)		15.6	74 Methyl 2,3-di-O-methyl-D- glucopyranosiduronic acid	Sirup	68
6 D-Glyceric acid, brucine salt	222		44 D-Mannono-γ-lactone	151	51.8 → 47	75 Methyl (methyl 2,3-di-O- methyl-D-glucopyranoside)	Sirup	76 (c 0.7, H ₂ O)
7 L-Glyceric acid (C ₃ H ₆ O ₄)	Gum	Levo	45 D-Mannono-γ-lactone tetra- acetate	119	52 (80% CH ₃ COCH ₃)	76 Methyl 2,3-di-O-methyl-D- glucopyranosiduronic phenylhydrazide	225-227	
8 Calcium L-glycerate dihydrate	134-135	-12 [30°]	46 D-Mannanamide	172-173	-17.3			
9 D-Arabonic acid (C ₅ H ₁₀ O ₆)	114-116	10.5 (c 6)	47 D-Mannono-δ-lactone	161-162	111.9 → 39.9 ⁶			
10 D-Arabono-γ-lactone (See also L-arabonic acid)	96	73.7	48 D-Mannonic phenylhydrazide	214-216	-8.1 [80°]			

11	L-Arabinic acid (C ₅ H ₁₀ O ₆)	118-119	-9.6 → -41.7 ⁴	49	α-D-Galacturonic acid monohydrate (C ₆ H ₁₂ O ₈)	159-160 (110-115 s.)	97.9 → 50.9	77	Methyl (methyl 2, 3, 4-tri-O-methyl-β-D-glucopyranoside) uronate	Sirup	87
12	L-Arabinamide	135-136	37.2	50	p-Bromophenylhydrazine salt of β-D-galacturonic acid p-bromophenylhydrazone	145-146	9±2 [22°] (c 0.7, CH ₃ OH)	78	Methyl 2, 3, 4-tri-O-methyl-β-D-glucopyranosiduronamide	183	137.5 (c 0.7, H ₂ O)
13	L-Arabinic phenylhydrazide	215		51	β-D-Galacturonic acid (C ₆ H ₁₀ O ₇)	160	27 → 55.6	79	α-D-Mannuronic acid monohydrate (C ₆ H ₁₂ O ₈)	(110 s.)	16.0 → -6.1 (c 6.8)
14	L-Arabinic acid tetraacetate (See also α-arabinic acid above)	135-135.5	-32 (c 1.5, CHCl ₃)	52	β-D-Galacturonic acid p-bromophenylhydrazone	150-151	11.5±2 [22°] (c 1.36, CH ₃ OH)	80	β-D-Mannopyranurono-γ-lactone	120-130 d.	89.3
15	β-Ribonic acid (C ₅ H ₁₀ O ₆)	112-113	-17.0	53	Methyl α-D-galacturonopyranoside dihydrate	113	129.9	81	β-D-Mannopyranurono-γ-lactone	165-167	-47.9 → -23.9
16	β-Ribono-γ-lactone	77		54	Methyl β-D-galacturonopyranoside monohydrate	134	-39.2	82	p-Bromophenylhydrazine salt of β-D-mannuronic p-bromophenylhydrazone	160 d.	64.5±1 (c 2.3, CH ₃ OH)
17	β-Ribonamide	136-137	16.5	55	Methyl (methyl-α-D-galactopyranoside) uronate monohydrate	142	125.4	83	2, 3, 4-Tri-O-methyl-β-D-mannopyranuronic acid	143-144 d.	48.5±1 (c 1.4, CH ₃ OH)
18	β-Ribonic acid tetraacetate	138-139	-24.4 (c 2.3, CHCl ₃)	56	Methyl (methyl-β-D-galactopyranoside) uronate	194	-45.6	84	Methyl (methyl 2, 3-di-O-methyl-β-D-mannopyranoside) uronate	174-175 d.	18.5±1 (c 0.75, C ₅ H ₅ N)
19	β-Xylonic acid (C ₅ H ₁₀ O ₆)		-2.9 → 20.1 ⁴	57	2-O-Methyl-β-D-galactopyranuronamide	173		85	2, 3, 4-Tri-O-methyl-β-D-mannopyranuronic acid	Sirup	30 (c 1.5, CH ₃ OH)
20	β-Xylono-γ-lactone	99-103	85.5 → 24.2	58	Methyl (methyl 2-O-methyl-α-D-galactopyranoside) uronate	Sirup	80	86	2, 3, 4-Tri-O-methyl-β-D-mannopyranuronic acid	Sirup	36.4
21	β-Xylonic acid tetraacetate	86-88	-2 (c 2, CHCl ₃)	59	Methyl 2-O-methyl-α-D-galactopyranosiduronamide	174	55 (c 0.05, CH ₃ OH)	87	Methyl (methyl 2, 3, 4-tri-O-methyl-β-D-mannopyranoside) uronate	Sirup	60 (c 10, H ₂ O)
22	Cadmium β-xylonate, cadmium bromide double salt dihydrate		8.8	60	Methyl 2, 3-di-O-methyl-β-D-galactofuranosiduronamide	122	-146 [16°]	88	2, 3, 4-Tri-O-methyl-β-D-mannosaccharodiamide	228	-17 (c 0.5, CH ₃ OH)
23	β-Galacturonic acid (C ₆ H ₁₂ O ₇)	122	-11.2 → -57.6 ⁴	61	2, 3, 6-O-methyl-β-D-galactopyranuronic acid	Sirup	62 [14°]	89	β-Tartaric acid (C ₄ H ₆ O ₆)	170	-15
24	β-Galactono-γ-lactone	112	-73 → -63.7	62	Methyl (methyl 2, 3-di-O-methyl-β-D-galactopyranoside) uronate	Sirup	7	90	L-Tartaric acid (C ₄ H ₆ O ₆)	170	15 [15°]
25	β-Galactonamide	172-172.5	30.2	63	2, 3, 4-Tri-O-methyl-α-D-galacturonic acid monohydrate	98-99	120 → 104	91	L-Tartaric acid diacetate trihydrate	58	-19.32
26	β-Galactonic phenylhydrazide	203	10.4	64	Methyl (methyl 2, 3, 4-tri-O-methyl-β-D-galactopyranoside) uronate	70	149.0 (c 1.2, CH ₃ COCH ₃)	92	Dimethyl L-tartrate	48, 61.5	2.74
27	β-Galactonic acid pentaacetate	131-132	12 (c 3, CHCl ₃)	65	β-D-Glucuronic acid (C ₆ H ₁₀ O ₇)	156	11.7 → 36.3	93	L-Tartaramide	195	106.5
28	β-Galactonic acid, 2-deoxy-2-"keto"- (C ₆ H ₁₀ O ₇)	169	-5	66	β-D-Glucopyranurono-γ-lactone	180	18.6	94	L-Malic acid (C ₄ H ₆ O ₅)	100	-2.3 (c 8.4)
29	2-Deoxy-2-"keto"-β-galactonic acid, brucine salt	172	-22.5 (50% C ₂ H ₅ OH)	67	α-D-Glucopyranurono-γ-lactone triacetate	110-112	203.6 (c 0.9, CHCl ₃)	95			
30	β-Gluconic acid (C ₆ H ₁₂ O ₇)	130-132 (110-112 s.)	-6.7 → 11.9 ⁴	68	β-D-Glucopyranurono-γ-lactone triacetate	194-195	84.1 (c 1.5, CHCl ₃)	96	Malic acid acetate	132	-6.84
31	β-Glucono-γ-lactone	134-136	67.5 → 17.7	69	Phenylhydrazide of β-glucuronic phenylhydrazone	182		97	Dimethyl malate	Sirup	
32	β-Gluconamide	143-144	31.2						BP ₁₁	129	
33	β-Gluconic phenylhydrazide	200	12						156-157		-37.9
34	β-Glucono-6-lactone	150-152	61.7 → 6.2								
35	β-Gluconic acid pentaacetate	110-111	11.5 (c 2, CHCl ₃)								
36	β-Gluconic acid, 2-deoxy-2-"keto"- (C ₆ H ₁₀ O ₇)		-81.7 (sodium salt)								
37	Methyl 2-deoxy-2-"keto"-β-gluconate	173	-82.1 → -77.4								
38	2-Deoxy-2-"keto"-β-glucono-γ-lactone triacetate	154	-60.4 (c 2.2, CHCl ₃)								

/1/ This table contains those sugar acids which are found free, as components in hydrolyzates of natural products, or as oxidation products of bacterial action on some natural monosaccharide or alditol. The literature has been covered through 1952 and partially through 1953. Unless otherwise stated, all data are for crystalline substances. /2/ The aldonic acids are listed first, arranged alphabetically in groups which are formulated according to increasing carbon content in the parent sugar. Then uronic acids, and finally, glycaric acids are similarly listed. It is to be noted that while acetate derivatives are given for a few of the aldonic acids not all of such derivatives have been made directly from the parent free acid. Since some have, however, the acetates listed have been given as a matter of completeness. /3/ Unless otherwise stated, the rotations are taken in water at concentrations less than 5 and at 20-25°C. Other temperatures are shown in brackets; c = grams of solute per 100 ml of solution. /4/ Equilibrates with the lactone. /5/ There is some claim that bacterial action on calcium β-gluconate produces L-guluronic acid. This fact is yet to be firmly established since no definitive derivative of L-guluronic acid has been produced. L-Guluronic forms the same phenylosazone as 5-deoxy-5-"keto"-β-gluconic acid. /6/ Passes through a minimum point in mutarotating.

9. CARBOHYDRATES: PHYSICAL AND CHEMICAL CHARACTERISTICS (Concluded)

Part VI: NATURAL PHOSPHATE ESTERS^{1,2}

PART VI: NATURAL PHOSPHATE ESTERS-77																	
Substance								Substance									
Hydrolysis Constant k ³ 1st Ester ⁴ Group		Temp °C	Medium	[α] Degrees ⁵	Wave Length ⁶	Compound	Conc.	Hydrolysis Constant k ³ 1st Ester ⁴ Group		Temp °C	Medium	[α] Degrees ⁵	Wave Length ⁶	Compound	Conc.		
1	Dihydroxyacetone phosphate	33.7	100	N HCl				35	D-Glyceric acid 2, 3-diphosphate (concluded)			-2 ± 0.3	D	Ba salt	6-17, (H ₂ O or 1 NHNO ₃)		
2	D-Fructose 1-phosphate	70	100	N HCl	-64.2 -39 -52.1	5461 5461 5461	Free acid Ba salt Brucine salt	11.3 6.1	36			-5.12	D	Na salt	6-14		
3								37				+4.6 ± 0.4 ¹⁴	D	Na salt			
4	D-Fructose 6-phosphate	4.4	100	N HCl	+3.6	D	Ba salt	10	38	α-L-Glycerophosphate (L-glycerol 1-phosphate)(L-glycerin 1-phosphate)	0.15	80	Water, pH 6.3	+1.0	D	Ag salt	6.5
5	D-Fructose 1, 6-diphosphate	52 ⁶	100	N HCl	+4.1	D	Free acid	13.6	39			-4.7	D	Dimethyl ether, dimethyl ester			
6	α-D-Galactose 1-phosphate	5.9	37	0.25 N HCl	+108	D	K salt	2.6	40			-5.3	D	Diethyl ether, diethyl ester			
7					+148 +92 +113	D D 5461	Free acid Ba salt Ba salt	1.7 (0.2 N HCl) 2.3	41			-2.8 ± 0.1	D	Glycerol-phosphorylcholine			
8	β-D-Galactose 1-phosphate	5.6	37	0.25 N HCl	+31.3	D	Trihydrate Ba salt	1.2	42	D-Mannose 6-phosphate	0.29	100	N HCl	+15.1 +3.5	5461 5461	Free acid Ba salt	1.7 0.7
9	D-Gluconic acid 6-phosphate	0.21	100	N HCl	+0.2 +18	5461 5461	Free acid Free acid lactone		43	β-D-Ribose 1-phosphate	1200	25	0.5 N HCl	-12.9	D	Free acid	
10	α-D-Glucose 1-phosphate	1.3	37	0.25 N HCl	+118	D	Free acid	1	44	D-Ribose 3-phosphate	4.5	100	0.25 N HCl	-9.7	D	Na salt	3.8
11		5 ⁷	33	N HCl	+75.5 +78 +90 +0.5 ⁸	D D 5461 D	Ba salt K salt dihydrate K salt dihydrate Dibrucine salt octahydrate ⁹	1.3 4 4 3	45	D-Ribose 5-phosphate	0.5	100	0.25 N HCl	+6.0	D	Ba salt	3.7
12	β-D-Glucose 1-phosphate	15 ⁷	33	N HCl	-20 ¹⁰	D	Dibrucine salt decahydrate ¹¹	1.7	46				+16.5 +20	D D	Free acid Free acid	3 (1 N HCl) (0.2 N HCl)	
13	D-Glucose 6-phosphate	0.23	100	N HCl	+35.7 +41.4 +18 +21.2 +21.2	D 5461 D 5461 D	Free acid Free acid Ba salt Ba salt K salt	0.7 8.4 1.3	47	β-D-Ribose, 2-deoxy-, 1-phosphate	13-17 ¹³		Acetate buffer pH 4.5				
14	α-D-Glucose 1, 6-diphosphate	0.78	30	N H ₂ SO ₄	+83 ± 4	D	Free acid	0.2	48	β-D-Ribose, 2-deoxy-, 5-phosphate	50 ¹³	100	N HCl				
15	β-D-Glucose 1, 6-diphosphate	3.15	30	N H ₂ SO ₄	-19 ± 2	D	Free acid	0.4	49	D-Ribulose 5-phosphate				-40	D	Free acid	
16	D-Glyceraldehyde 3-phosphate ¹²	37.5	100	N HCl	+12	D	Free acid		50	L-Sorbose 1-phosphate	60 ¹³	100	N HCl	-16.5 -7.2	D D	Mono K salt Ba salt dihydrate	2 2.5 (0.1 N HCl)
17	D-Glyceric acid 2-phosphate				+24.3 -68	D D	Free acid Free acid	(Molybdate ion)	51	Trehalose monophosphate				+185 +132 +31	5461 5461 5461	Free acid Ba salt Brucine salt monohydrate	2.4 3.2 0.8
18	D-Glyceric acid 3-phosphate	1.8 ¹³	125	N HCl	-14.5 -725	D D	Ba salt Ba salt	(Molybdate ion)	52	Unidentified ketoheptose monophosphate	4	100	N HCl	+8	5461	Ba salt	
19	D-Glyceric acid 1, 3-diphosphate	26	38	Water	Very small	11			53	D-Xylose 5-phosphate	4	100	N HCl	+3.2 +5	D D	Na salt Ba salt	5 2
20	D-Glyceric acid 2, 3-diphosphate				-4 ± 0.5 -4	D D	Ba salt Na salt	15 (aq. HNO ₃) 28	54	D-Xylulose phosphate (D-xyloketose 1-phosphate)	86	100	N HCl				

/1/ In preparing this table the literature has been covered through 1952, and Chem. Abs. coverage has extended through Sept., 1953. /2/ Unless otherwise noted all data are for crystalline material. Phosphate esters known only from strictly chemical syntheses are excluded. Included are some compounds which have not actually been isolated as such, but for which evidence for probable existence or structure is at hand. /3/ Values are k x 10³. /4/ The 1st ester group is that one that lies farthest in the sugar carbon chain structure from the primary hydroxyl carbon (or asymmetric center) which determines the parent sugar's D or L configuration. /5/ Taken at 20-25°C in water unless otherwise noted. /6/ D represents the sodium D line, 5896. /7/ Constants were determined on the dibrucine salts. /8/ Rotation taken at 27°C. /9/ Brucine salt melts at 173-178°C. /10/ Rotation taken at 29°C. /11/ Brucine salt melts at 160-165°C. /12/ The compound fuses above 75°C, Fischer, H. O. L., and Baer, E., Ber. 65:337, 1040, 1932. /13/ Calculated by the contributors of this table from the data of the original investigator, using k = 0.30/time in min for 50% hydrolysis. /14/ The signs of these rotations are actually opposite, as taken from the original journal articles. /15/ Deoxy-β-D-ribose 1-phosphate cyclohexylamine salt sinters and decomposes at 152°C.

10. GLYCOSIDES: CHARACTERISTICS, OCCURRENCE, AND USES

Glycoside	Formula	M.P. ¹ °C	Rotation [α] _D	Solubility ¹			Occurrence	Uses	Aglycone	M.P. ¹ °C	Rotation [α] _D	Sugar
				H ₂ O	Alc.	Eth., etc.						
				g/100 ml								
1 Absinthin	C ₃₀ H ₄₀ O ₈	68		sl. s.	s.	s. eth., chl., bz., NaOH	Wormwood	Anemia; anorexia; achlorhydria; constipation.				Glucose
2 Aesculin	C ₁₅ H ₁₆ O ₉	205 d. ²	-38	0.175	5	sl. s. eth., s. h. chl., NaOH	Horse chestnut tree ^{3,4}	Instead of quinine in intermittent fever; neuralgia; lupus vulgaris.	Aesculetin	270 d.		Glucose
3 Aloin	Mixture	220 ²	-42	s.	s.	sl. s. eth., chl.	Aloe spp	Chronic constipation; amenorrhea.				Pentoses
4 Amygdalin	C ₂₀ H ₂₇ O ₁₁ N	228 ²		8.3 h.	sl. s.	i. eth.	Almonds	Expectorant.	p-Mandelonitrile			Glucose
5 Apiin	C ₂₆ H ₄₂ O ₁₀	195-200	-64	12.5	7.7	i. eth., CS ₂ , chl.	Celery; parsley	Diuretic; insecticide; dropsy.	Apigenin	350		Glucose; apiose
6 Arbutin	C ₁₂ H ₁₆ O ₇	148		s.	s.	sl. s. eth.	Cranberry, pear tree ³	Diuretic.	Hydroquinone	170		Glucose
7 Barbaloin	C ₂₀ H ₁₈ O ₈	208		sl. s.	s.	i. eth., chl.	Aloe spp	Chronic constipation.	Aloe-emodin	224		Glucose
8 Bryonin	C ₄₈ H ₆₆ O ₁₈	136 d.		s.	s.	s. eth., NaOH; i. chl.	Bryonia alba	Dropsy; congested liver; pericarditis; rheumatism.	Bryogenin			Glucose
9 Carminic acid	C ₂₂ H ₂₀ O ₁₃	185	-68	0.5	sl. s.	i. eth.	Cochineal	Indicator. Pigment in color photography, paints, bacteriology.	Carminic acid			
10 Coniferin	C ₁₆ H ₂₂ O ₈	247	0	0.05	s.	sl. s. eth., chl.	Conifers; sugar beet	Preparation of vanilla.	Coniferyl alcohol	73-74		Glucose
11 Convallatoxin	C ₂₉ H ₄₂ O ₁₀	155-168		sl. s.	s.	i. eth.; s. acet.	Lily of the valley	Cardiac glycoside.	Strophanthidin	235	+43.1	Rhamnose
12 Convolvulin	C ₅₄ H ₉₆ O ₂₇	186 d. ²		sl. s.	sl. s.	i. eth., chl.	Jalap resin, Canadian hemp	Purgative. Cardiotonic.	Methylethylacetic acid; tiglic acid			Glucose; rhodose
13 Crocin	C ₄₄ H ₆₄ O ₂₆	139	+35	s.		s. chl., me. al.	Saffron, crocus, gardenia	Plays role in sex process of algae.	Crocin	285		Gentiobiose
14 Cymaridin	C ₃₀ H ₄₄ O ₉	125 d. ²	-115	sl. s.	s.	i. eth.; s. NaOH	Daphne	Cardiac stimulant; tonic.	Strophanthidin	235	+43.1	Cymarose
15 Daphnin	C ₁₅ H ₁₆ O ₉	155-183	-176	i.		sl. s. eth.; s. chl., CCl ₄		Inflammation and vesication of skin; epispastic.	7,8-Dihydroxycoumarin	253 d.		Glucose
16 Diginin	C ₂₈ H ₄₀ O ₇	235 d. ²	-54	s.	1.8 abs.	i. eth., chl.	Digitalis purpurea ³	Digitalis glycoside. Cardiotonic.	Diginigenin	115	-226	Giginose
17 Digitonin	C ₅₅ H ₉₀ O ₂₉	256	+4.8	0.001	1.7	i. eth.	Digitalis purpurea ⁶	Test for cholesterol and some other sterols.	Digitogenin	250	-81	Glucose; galactose
18 Digitoxin	C ₄₁ H ₆₄ O ₁₃	265 d.	+13.3	0.001	0.45	i. eth., chl.	Digitalis purpurea	Congestive heart failure. Cardiotonic.	Digitoxigenin + digitose	253	+19.1	Digitose
19 Digoxin	C ₄₁ H ₆₄ O ₁₄	179-180	-58	s.	s.	i. eth.; s. acet.	Digitalis lanata	Digitalis glycoside. Cardiotonic.	Digoxigenin + digitoxose	222	+27	
20 Gaultherin	C ₁₉ H ₂₆ O ₁₂	272	-51	sl. s.	0.98	i. eth.; s. acet.	Wintergreen plant	Source of methyl salicylate.	Methyl salicylate	-8.6	+1.2	Glucose; xylose
21 Gitonin	C ₅₀ H ₈₂ O ₂₃	285	+3.5	sl. s.		s. eth.; i. chl., acet.	Digitalis purpurea	Similar to digitonin.	Gitogenin	272	-61	Galactose; xylose
22 Gitoxin	C ₄₁ H ₆₄ O ₁₄	235-237		sl. s.	s.	sl. s. eth.; s. chl.	Digitalis lanata	Minor digitalis glycoside.	Gitoxigenin	235	+38.5	Digitoxose
23 Gratiolin	C ₄₃ H ₇₀ O ₁₅	260-262	-76	v. sl. s.	sl. s.	i. eth., chl.; me. al.	Gratiola glucoside	Cathartic; emetic; diuretic; dropsy.	Gratiogenin	198		Glucose
24 Hesperidin	C ₂₈ H ₃₄ O ₁₅	176-178	-66	s.	s.	sl. s. eth., chl.	Citrus plants	Purpura; vascular complications; hypertension; anti-hyaluronidase.	3',5,7-Trihydroxy-flavanone	390 d.		Glucose
25 Indican	C ₁₄ H ₁₇ O ₆ N	110 ²	-52	0.1	25	i. eth., chl.	Indigofera spp	Jaundice; constipation; amenorrhea.	Indoxyl	390		Glucose
26 Iridin	C ₂₄ H ₂₆ O ₁₃ N	131-150	0	sl. s.	s.	s. eth., chl.	Rhizome of iris	Chronic constipation.	Iridogenin	186		Glucose
27 Jalapin	C ₃₄ H ₅₆ O ₁₆	175 ²		sl. s.	s.	i. eth.	Scammony resin	Angina pectoris; coronary thrombosis; bronchial asthma.	Jalapinolic	67-69		Various
28 Khellinin	C ₁₉ H ₂₀ O ₁₀	185 d.	-32.5	1.2	1	sl. s. eth., chl.	Toothpick ammi ⁶	As for digitalis.	2-Hydroxymethyl-5-methoxy-furanochrome	155		Glucose
29 Ouabain	C ₂₉ H ₄₄ O ₁₂	110 ²	-52	0.1	25	i. eth., chl.	Strophanthus gratus ⁶	Additive to lubricating oils.	Ouabagenin	255	+11.3	Rhamnose
30 Phlorizin	C ₂₁ H ₂₄ O ₁₀	154-156	-50	s.	s.	sl. s. eth., chl.	Fruit trees ⁴	Coloring; flavoring.	Phloretin	271		Glucose
31 Picrocrocin	C ₁₆ H ₂₆ O ₇	182-185 ²		i. c.	s.	i. eth.; s. NaOH	Crocus	Astringent; tonic; textile dye.	Safranin	314 d.		Glucose
32 Quercitrin	C ₂₁ H ₂₀ O ₁₁	215 d.		sl. s. c.	sl. s.	i. eth., chl.	Quercitron ⁴	Vascular purpura; hypertension; diabetes; inc. capillary fragility.	Quercetin	313-4		Glucose; rhamnose
33 Rutin	C ₂₇ H ₃₀ O ₁₆	199-201	-67	4	1	i. eth., chl.	Buckwheat plant	Analgesic. Rheumatism; malaria; typhoid; chorea.	Saligenin	87		Glucose
34 Salicin	C ₁₃ H ₁₈ O ₇	240	-66	s.	s. h.	sl. s. eth.	Poplar, willow ⁴	Production of progesterone, testosterone	Sarsasapogenin	200	-75	Glucose; rhamnose
35 Sarsasapogenin	C ₄₅ H ₇₄ O ₁₇	285 d.	-60	i.	s. h.	i. eth., chl.	Solanum	Vomiting of pregnancy; asthma; epilepsy; locomotor ataxia; tetanus.	Solanidine	219	-29	Glucose; galactose; rhamnose
36 Solanine	C ₄₅ H ₇₃ O ₁₅ N							Tuberculosis; susceptible gram-negative bacteria.	Streptidine			L-Streptose
37 Streptomycin · HCl	C ₂₁ H ₃₉ O ₁₂ · N ₇ · 3HCl	210-5 d.		v. s.	sl. s.	v. sl. s. eth., chl.	Cultures of Streptomyces griseus	Tanning; mordant in dyeing and printing.	Gallic acid	235 d.		Glucose
38 Tannic acid	C ₇₆ H ₅₂ O ₄₆						Oak, sumac ⁴					

/1/ Abbreviations: abs. = absolute; acet. = acetone; bz. = benzene; c. = cold; chl. = chloroform; d. = decomposes; eth. = ether; h. = hot; i. = insoluble; me. al. = methyl alcohol; s. = soluble; sl. = slightly; v. = very. /2/ Hydrated salt. /3/ Leaves. /4/ Bark. /5/ It has been reported that this compound is therapeutically inactive. /6/ Seeds.

11. FATTY ACIDS: PHYSICAL AND CHEMICAL CHARACTERISTICS

Common Name	Systematic Name	Formula	Molec- ular Weight	M. P. or Fr. P.*1 °C	Boiling Point ² °C	Specific Gravity ³	Refractive Index ⁴ n_D^{20}	Neutral- ization Value ⁵	Iodine Value (Calculated) ⁶	Solubility ⁷	Source
Saturated Fatty Acids											
1 Formic	Methanoic	HCOOH	46.0	8.6	100.8	1.220 ²⁰	1.3714 ²⁰	1219		s. w.	Red ant
2 Acetic	Ethanoic	CH ₃ COOH	60.1	16.7	118.2	1.049 ²⁰	1.3715 ²³	934.2		s. w.	Vinegar
3 Propionic	Propanoic	C ₂ H ₅ COOH	74.1	-22.0	141.1	0.992 ²⁰	1.3874 ²⁰	757.3		s. w., al., eth., chl.	
4 Butyric	Butanoic	C ₃ H ₇ COOH	88.1	-7.9	162.7 ⁶⁹	0.9587 ²⁰	1.3390 ²⁰	636.8		s. w., eth., al.	Butter fat
5 Valeric	Pentanoic	C ₄ H ₉ COOH	102.1	-34.5	187			549.3		sl. s. w.; s. al., eth.	
6 Caproic	Hexanoic	C ₅ H ₁₁ COOH	116.2	-3.9	205.3	0.9313 ¹⁵	1.4163 ²⁰	483.0		sl. s. w.; s. eth., al.	Butter fat, palm oil
7 Enanthic	Heptanoic	C ₆ H ₁₃ COOH	130.2	-8.9	223.5	0.9221 ¹⁵	1.4130 ²⁰	431.0		v. sl. s. w.; s. al., eth.	Violet leaf oil
8 Caprylic	Octanoic	C ₇ H ₁₅ COOH	144.2	16.5*	239.3	0.9088 ⁴⁰	1.4285 ²⁰	389.1		v. sl. s. w.; s. eth., al., bz	Butter fat, coconut oil
9 Pelargonic	Nonanoic	C ₈ H ₁₇ COOH	158.2	12.2*	254			354.6		v. sl. s. w.; s. al., eth., chl.	
10 Capric	Decanoic	C ₉ H ₁₉ COOH	172.3	31.3*	268.7	0.8858 ⁴⁰	1.4285 ⁴⁰	325.7		sl. s. w.; s. eth., al.	Butter fat, coconut oil
11 Undecylic	Undecanoic	C ₁₀ H ₂₁ COOH	186.3	28.3*	295			301.2		s. al., eth., chl.	
12 Lauric	Dodecanoic	C ₁₁ H ₂₃ COOH	200.3	43.9*	225 ¹⁰⁰	0.8690 ⁵⁰	1.4261 ⁶⁰	280.1		sl. s. h. w.; s. acet., al., eth.	Laurel kernel oil
13 Tridecyllic	Tridecanoic	C ₁₂ H ₂₅ COOH	214.3	41.8*	236 ¹⁰⁰			261.8		s. al., eth.	
14 Myristic	Tetradecanoic	C ₁₃ H ₂₇ COOH	228.4	54.1*	250.5 ¹⁰⁰	0.8622 ⁵⁴	1.4273 ⁷⁰	245.7		s. al., eth., acet., chl., glac. acet. a.	Nutmeg, butter fat
15 Palmitic	Hexadecanoic	C ₁₅ H ₃₁ COOH	256.4	62.7*	268 ¹⁰⁰	0.8527 ⁶²	1.4339 ⁶⁰	218.8		s. h. al., eth.	Palm oil
16 Stearic	Octadecanoic	C ₁₇ H ₃₅ COOH	284.5	69.6*	291 ¹⁰⁰	0.9408 ²⁰	1.4332 ⁷⁰	197.2		s. al., eth., acet., bz., CS ₂ .	Mutton tallow, cocoa butter
17 Arachidic	Eicosanoic	C ₁₉ H ₃₉ COOH	312.5	75.4	203-205 ¹	0.8240 ¹⁰⁰	1.4250 ¹⁰⁰	179.5		s. chl., eth.	Peanut oil
18 Behenic	Docosanoic	C ₂₁ H ₄₃ COOH	340.6	80.0	306 ⁶⁰	0.8221 ¹⁰⁰	1.4270 ¹⁰⁰	164.7		sl. s. eth., al.	Peanut oil, behen oil
19 Lignoceric	Tetracosanoic	C ₂₃ H ₄₇ COOH	368.6	84.2		1.4287 ¹⁰⁰		152.2		sl. s. al.; s. acet., bz., eth.	Beech-tar paraffin
20 Cerotic	Hexacosanoic	C ₂₅ H ₅₁ COOH	396.7	87.7		0.8198 ¹⁰⁰	1.4301 ¹⁰⁰	141.4		s. h. me. al., h. al., h. bz., h. chl., h. acet.	Beeswax, wool wax
21 Montanic	Octacosanoic	C ₂₇ H ₅₅ COOH	424.7	90.9		0.8191 ¹⁰⁰	1.4313 ¹⁰⁰	132.1		s. pet. eth., h. al., glac. acet. a.	Beeswax, montan wax
22 Melissic	Triacontanoic	C ₂₉ H ₅₉ COOH	452.9	93.6			1.4323 ¹⁰⁰	123.9		s. h. al., chl., CS ₂ .	Beeswax, mineral waxes
23 Lacceroic	Dotriacontanoic	C ₃₁ H ₆₃ COOH	480.8	96.2				116.7		s. bz., acet., a., chl.	Stick-lac wax
24 Geddic	Tetratriacontanoic	C ₃₃ H ₆₇ COOH	508.9	98.3-0.5				110.2		s. bz., acet., chl.	Ghedda wax
25	Hexatriacontanoic	C ₃₅ H ₇₁ COOH	536.9	99.9				104.5			
Unsaturated Fatty Acids (Monoethenoid)											
26	2-Hexenoic	C ₆ H ₁₀ O ₂	114.1	32		0.954 ⁰	1.4466 ⁴⁰	491.5	222.5	s. eth., bz.	Japanese peppermint oil
27	4-Decenoic	C ₁₀ H ₁₈ O ₂	170.2		148-150 ¹³	0.9197 ²⁰	1.4497 ²⁰	329.6	149.1	s. al., eth.	Tohaku oil
28	9-Decenoic	C ₁₀ H ₁₈ O ₂	170.2		143-8 ¹⁵	0.9238 ¹⁵	1.4507 ¹⁵	329.6	149.1		Butter fat, whale oil
29	4-Dodecenoic	C ₁₂ H ₂₂ O ₂	198.3	1.0-1.3	170-172 ¹³	0.9081 ²⁰	1.4529 ²⁰	282.9	128.0	s. eth., chl., bz., pet. eth.	Tohaku oil
30	5-Dodecenoic	C ₁₂ H ₂₂ O ₂	198.3			0.9130 ¹⁵	1.4535 ¹⁵	282.9	128.0	s. eth., chl., bz., pet. eth.	Herring oil, whale oil
31	9-Dodecenoic	C ₁₂ H ₂₂ O ₂	198.3					282.9	128.0	s. eth., chl., bz., pet. eth.	Butter fat, cochineal wax
32	4-Tetradecenoic	C ₁₄ H ₂₆ O ₂	226.4	18.0-0.5	185-188 ¹³	0.9055 ¹⁵	1.4575 ¹⁵	247.9	112.2	s. eth., bz.	Tsuzu seeds
33	5-Tetradecenoic	C ₁₄ H ₂₆ O ₂	226.4			0.9046 ²⁰	1.4552 ²⁰	247.9	112.2	s. eth., bz.	Whale oil
34	9-Tetradecenoic	C ₁₄ H ₂₆ O ₂	226.4			0.9018 ²⁰	1.4549 ²⁰	247.9	112.1	s. eth., bz.	Butter fat, whale oil
35	9-Hexadecenoic	C ₁₆ H ₃₀ O ₂	254.4	-1				220.5	99.8	s. eth., bz.	Marine oils, milk fat
36	6-Octadecenoic	C ₁₈ H ₃₄ O ₂	282.5	32-33	237-238 ¹⁸	0.8824 ³⁵	1.4535 ⁴⁷	198.6	89.9	s. al., eth.	Parsley seed oil
37	9-Octadecenoic	C ₁₈ H ₃₄ O ₂	282.5	13	200-201 ^{1.2}	0.8952 ⁰	1.4582 ²⁰	198.6	89.9	s. acet., me. al., eth.	Olive oil, pork fat
38	11-Octadecenoic	C ₁₈ H ₃₄ O ₂	282.5	6-10				198.6	89.9	s. acet., me. al., eth.	Butter fat, mutton fat
39	9-Eicosenoic	C ₂₀ H ₃₈ O ₂	310.5					180.7	81.8	s. acet., me. al.	Sperm oil, cod-liver oil
40	11-Eicosenoic	C ₂₀ H ₃₈ O ₂	310.5	50	267 ¹⁵			180.7	81.8	s. al.	Jajoba oil
41	11-Docosenoic	C ₂₂ H ₄₂ O ₂	338.6					165.7	75	s. al.	Marine oils
42	13-Docosenoic	C ₂₂ H ₄₂ O ₂	338.6	33.5	241-243 ⁵			165.7	75.0	v. s. al., eth.	Mustardseed oil
43	15-Tetracosenoic	C ₂₄ H ₄₆ O ₂	366.6	42.5-43				153.0	69.2	s. al., eth., acet.	Shark liver oil
44	17-Hexacosenoic	C ₂₆ H ₅₀ O ₂	394.7					142.2	64.3	s. eth., chl., bz., pet. eth.	Tallow wood
45	21-Triacontenoic	C ₃₀ H ₅₈ O ₂	450.8					124.5	56.3	s. eth., chl., bz., pet. eth.	Tallow wood
Unsaturated Fatty Acids (Polyethenoid)											
46	9,12-Octadeca- dienoic	C ₁₈ H ₃₂ O ₂	280.4	-5.0 to -5.2	20.2 ^{1.4}	0.9038 ¹⁸	1.4715 ^{1.5}	200.1	181.0	s. acet., me. al., eth.	Soybean oil, linseed oil
47	6,10,14-Hexa- decatrienoic	C ₁₆ H ₂₆ O ₂	250.4			0.9324 ¹⁵	1.4876 ¹⁵	224.1	304.2	s. acet., al., eth., pet. eth.	Sardine oil
48	9,12,15-Octa- decatrienoic	C ₁₈ H ₃₀ O ₂	278.4	-14.4 to -14.5	157-158 ^{0.001}	0.9046 ²⁰	1.4780 ²⁰	201.5	273.5	s. acet., al., eth., pet. eth.	Linseed oil, hempseed oil
49	9,11,13-Octa- decatrienoic	C ₁₈ H ₃₀ O ₂	278.4	48	235 ¹²		1.5112 ⁵⁰	201.5	273.5	v. s. eth.; s. al., CS ₂	Tung oil, esang seed oil
50	4,8,12,15-Octa- decetraenoic	C ₁₈ H ₂₈ O ₂	276.4			0.9334 ¹⁵	1.4930 ¹⁵	203.0	372.6	s. acet., al., eth., pet. eth.	Sardine oil
51	9,11,13,15-Octa- decetraenoic	C ₁₈ H ₂₈ O ₂	276.4	85-6				203.0	367.3	s. pet. eth., eth.	"Akarittom" seed fat

Unsaturated Fatty Acids (Polyethenoid) (Concluded)												
52	Arachidonic	5, 8, 11, 14-Eicosa-tetraenoic	C ₂₀ H ₃₂ O ₂	304.5	-49.5			1.4824 ²⁰	184.3	333.5	s. acet., me. al.	Glandular organs, liver lipids
53	Timnodonic	4, 8, 12, 15, 18-Eicosa-pentaenoic	C ₂₀ H ₃₀ O ₂	302.4					185.5	419.7	s. eth., chl., bz., pet. eth.	Sardine oil
54	Clupanodonic	4, 8, 12, 15, 19-Docosa-pentaenoic	C ₂₂ H ₃₄ O ₂	330.5	-78		0.9385 ¹⁵	1.5039 ¹⁵	169.8	384.0	s. acet., eth.	Herring oil, cod-liver oil
55	Nisinic	4, 8, 12, 15, 18, 21-Tetracosahexaenoic	C ₂₄ H ₃₆ O ₂	356.5					157.4	427.2	s. eth., chl., bz., pet. eth.	Sardine oil, cod-liver oil
Hydroxy- and Keto-fatty Acids												
56	Sabinic	12-Hydroxy-dodecanoic	C ₁₂ H ₂₄ O ₃	216.2	84				259.5		s. al., h. bz.	Juniper wax
57	Ipurolic	3, 11-Dihydroxy-tetradecanoic	C ₁₄ H ₂₈ O ₄	260.2	100-101				215.6		s. eth., chl.	Japanese morning glory seed
58	Convolvulinolic	11-Hydroxy-pentadecanoic	C ₁₅ H ₃₀ O ₃	258.2	63, 5-64				217.3		s. eth., pet. eth., chl., al.	Convolvulin resin
59	Jalapinolic	11-Hydroxy-hexadecanoic	C ₁₆ H ₃₂ O ₃	272.3	68-69				206.0		s. eth., al., pet. eth.	Jalap-root wax
60	Juniperic	16-Hydroxy-hexadecanoic	C ₁₆ H ₃₂ O ₃	272.3	95				206.0		s. bz., eth., al.	Conifer waxes
61	Dihydroxystearic	9, 10-Dihydroxy-octadecanoic	C ₁₈ H ₃₆ O ₄	316.5	cis 95 trans 132				177.3		s. eth., h. w., al. (cis); pet. eth., h. al(trans).	Castor oil
62	Phellonic	2-Hydroxy-decosanoic	C ₂₂ H ₄₄ O ₃	356.6	88-91				157.3		s. chl., eth., acet., pyr., glac. acet. a.	Cork, subeine, brain lipids
63	Cerebronic	2-Hydroxy-tetracosanoic	C ₂₄ H ₄₈ O ₃	384.6	99, 5 - 100, 5				145.9		s. eth., pyr., acet., h. al.	Brain lipids
64	Hydroxycerotic	2-Hydroxy-hexacosanoic	C ₂₆ H ₅₂ O ₃	412.7	86, 5				135.9		s. eth., acet., pyr., glac. acet. a.	Brain lipids
65	Lactarinic	6-Keto-octa-decanoic	C ₁₈ H ₃₄ O ₃	298.4	86				188.0		s. h. al., eth., chl.	Lactarius mushrooms
66	Ricinoleic	12-Hydroxy-9-octadecenoic	C ₁₈ H ₃₄ O ₃	298.4	5.5		0.940 ^{27.4}	1.4716 ²⁰	188.0	170.1	s. acet., pet. eth.	Castor oil
67	Hydroxynervonic	2-Hydroxy-9-tetracosenoic	C ₂₄ H ₄₆ O ₃	382.6					146.6	66.3	s. eth., chl., bz.	Brain lipids
Branched Chain and Cyclic Fatty Acids												
68	Isobutyric	2-Methyl propanoic	C ₄ H ₈ O ₂	88.1	-46	155	0.95296 ¹⁵	1.39646 ¹⁵	636.8		s. al., pet. eth.	
69	Isovaleric	3-Methyl butanoic	C ₅ H ₁₀ O ₂	102.1	-51	176.7	0.937 ¹⁵	1.40178 ^{22.4}	549.34		s. w., al., chl., eth.	Dolphin oil
70	Isopalmitic	14-Methyl penta-decanoic	C ₁₆ H ₃₂ O ₂	256.4	62, 4				218.79		s. acet., pet. eth.	
71	Isostearic	16-Methyl hepta-decanoic	C ₁₈ H ₃₆ O ₂	284.5	69, 5				197.22		s. acet., pet. eth.	
72	Tuberculostearic	10-Methyl octa-decanoic	C ₁₉ H ₃₈ O ₂	298.5	10-11		0.8771 ²⁵	1.4512 ²⁵	187.95		s. eth., al., acet.	Wax of tubercle bacilli
73	Phytomonic		C ₂₀ H ₄₀ O ₂	312.5	24				179.5		s. eth., al.	Crown gall bacilli
74	Phthioic		C ₂₆ H ₅₂ O ₂	396.7	20-21		0.8763 ²⁵	1.4628 ²⁵	141.5		s. acet., eth.	Tubercle bacilli
75	Mycocerosic		C ₃₀ H ₆₀ O ₂	452	27-28			1.4532 ⁴⁰	124.1		s. eth., chl.	Tubercle wax
76	Mycolic		C ₈₈ H ₁₇₂ O ₄	1294.2	54-56				43.35		s. eth.	Human tubercle bacilli
77	Hydnocarpic	11-(2-Cyclopentenyl)-undecanoic	C ₁₆ H ₂₈ O ₂	252.4	59-60				222.3	100.6	s. pet. eth., al., chl.	Chaulmoogra oil
78	Chaulmoogric	13-(2-Cyclopentenyl)-tridecanoic	C ₁₈ H ₃₂ O ₂	280.4	68, 0-.5	247-248 ²⁰			200.1	90.5	s. acet., chl., eth.	Chaulmoogra oil
79	Gorlic	13-(2-Cyclopentenyl)-6-tridecanoic	C ₁₈ H ₃₀ O ₂	278.4	6(liq)	232.5	0.9436 ²⁵	1.4782 ²⁵	201.5	182.5	s. acet.	Chaulmoogra oil
80	Tariric	6-Octadecynoic	C ₁₈ H ₃₂ O ₂	280.4	liquid				200.06	181.0	s. h. al.	

/1/ * = freezing point. /2/ At atmospheric pressure (760 mm of mercury) unless otherwise indicated by specific pressure in superscript. /3/ At temperature indicated in superscript referred to water at 4° C. /4/ Refractive index (n) is given for the sodium D-line at temperature shown in superscript. /5/ mg KOH required to neutralize one g of acid. /6/ Grams of iodine absorbed by 100 g of acid. /7/ a. = acid; acet. = acetone; acet. a. = acetic acid; al. = alcohol; bz. = benzene; chl. = chloroform; eth. = ether; glac. = glacial; h. = hot; me. = methyl; pet. = petroleum; pyr. = pyridine; s. = soluble; sl. = slightly; v. = very; w. = water.

12. FATS AND OILS: PHYSICAL AND CHEMICAL CHARACTERISTICS

Values are considered typical rather than average, and frequently represent specific analyses for particular samples (especially in the case of the constituent fatty acids). Extreme variations may occur, depending on a number of variables, such as source, treatment, and age of a fat or oil.

Fat or Oil	Constants					Constituent Fatty Acids, g/100 g total fatty acids														
	Melting or *Solidi- fication Point °C	Specific Gravity or *Density 15°/15°C ¹	Refractive Index n _D ^{40°C} ²	Iodine Value	Saponi- fication Value	Saturated								Unsaturated						
						Caproic	Caprylic	Capric	Lauric	Myristic	Palmitic	Stearic	Arachidic	Palmitoleic	Oleic	Linoleic	Linolenic	C ₂₀ Polyethenoic	C ₂₂ Polyethenoic	Others
Vegetable Fats and Oils																				
1 Babassu oil (<i>Attalea funifera</i>)	22-26	*0.893 ⁶⁰	1.443 ⁶⁰	15.5	247	0.2	4.8	6.6	44.1	15.4	8.5	2.7	0.2		16.1	1.4				
2 Castor oil (<i>Ricinus communis</i>)	*-18.0	0.961	1.4770	85.5	180.3					2.4					7.4	3.1				+3
3 Cocoa butter (<i>Theobroma cacao</i>)	34.1	0.964	1.4568	36.5	193.8						24.4	35.4			38.1	2.1				
4 Coconut oil (<i>Cocos nucifera</i>)	25.1	0.924	1.4493	10.4	268	0.8	5.4	8.4	45.4	18.0	10.5	2.3	0.4 ⁴	0.4	7.5	Trace				
5 Corn oil (<i>Zea mays</i>)	*-20.0	0.922	1.4734	122.6	192.0					1.4	10.2	3.0		1.5	49.6	34.3				
6 Cottonseed oil (<i>Gossypium hirsutum</i>)	*-1.0	0.917 ^{25/25}	1.4735	105.7	194.3					1.4	23.4	1.1	1.3	2.0	22.9	47.8				
7 Linseed oil (<i>Linum usitatissimum</i>)	*-24.0	0.938	1.4782 ²⁵	178.7	190.3					6.3	2.5	0.5			19.0	24.1	47.4			+5
8 Mustard oil (<i>Brassica alba</i>)		0.9145 ⁶	1.4756	102 ⁶	174 ⁶					1.3 ⁷					27.2 ⁷	16.6 ⁷	1.8 ⁷			+8
9 Neem oil (<i>Azadirachta indica</i>)	-3	0.917 ⁶	1.4615 ⁶	71 ⁶	194.5 ⁶					2.6 ⁷	14.1 ⁷	24.0 ⁷	0.8 ⁷		58.5 ⁷					
10 Nigerseed oil (<i>Guizotia abyssinica</i>)		0.925 ⁶	1.471 ⁶	128.5 ⁶	190 ⁶					3.3 ⁷	8.2 ⁷	4.8 ⁷	0.5 ⁷		30.3 ⁷	57.3 ⁷				
11 Oiticica oil (<i>Licania rigida</i>)		0.974 ^{25/25}		140-180						11.3 ⁹					6.2					+10
12 Olive oil (<i>Olea Europaea sativa</i>)	*-6.0	0.918	1.4679	81.1	189.7					Trace	6.9	2.3	0.1		84.4	4.6				
13 Palm oil (<i>Elaeis guineensis</i>)	35.0	0.915	1.4578	54.2	199.1					1.4	40.1	5.5			42.7	10.3				
14 Palm kernel (<i>E. guineensis</i>)	24.1	0.923	1.4569	37.0	219.9		2.7	7.0	46.9	14.1	8.8	1.3			18.5	0.7				
15 Peanut oil (<i>Arachis hypogaea</i>)	*3.0	0.914	1.4691	93.4	192.1					8.3	3.1	2.4			56.0	26.0				+11
16 Perilla oil (<i>Perilla ocimoides</i>)		*0.935 ¹⁵	1.481 ²⁵	195	192					9.6 ⁹					17.8		17.5			
17 Poppyseed oil (<i>Papaver somniferum</i>)	*-15	0.925 ⁵	1.4685 ⁵	135 ⁵	194 ⁵					4.8 ⁷	2.9 ⁷				30.1 ⁷	62.2 ⁷				
18 Rapeseed oil (<i>Brassica campestris</i>)	*-10	0.915	1.4706	98.6	174.7					1					32	15	1			+12
19 Safflowerseed oil (<i>Carthamus tinctorius</i>)		*0.900 ⁶⁰	1.462 ⁶⁰	145	192					6.8 ⁹					18.6	70.1	3.4			
20 Sesame oil (<i>Sesamum indicum</i>)	*-6.0	0.919 ^{25/25}	1.4646	106.6	187.9					9.1	4.3	0.8			45.4	40.4				
21 Soybean oil (<i>Soja hispida</i>)	*-16.0	0.927	1.4729	130.0	190.6				0.2	0.1	9.8	2.4	0.9	0.4	28.9	50.7	6.5			+13
22 Sunflowerseed oil (<i>Helianthus annuus</i>)	*-17.0	0.923	1.4694	125.5	188.7						5.6	2.2	0.9		25.1	66.2				
23 Tung oil (<i>Aleurites fordii</i>)	*-2.5	0.934	1.5174 ²⁵	168.2	193.1						4.6 ⁹				4.1	0.6				+14
24 Wheat germ oil (<i>Triticum vulgare</i>)				125								16.0 ⁹			28.1	52.3	3.6			
Land-animal Fats and Oils																				
25 Butter fat	32.2	0.911 ^{40/15}	1.4548	36.1	227	2.0	0.5	2.3	2.5	11.1	29.0	9.2	2.4	4.6	26.7	3.6				+15
26 Human depot fat	*15	0.918	1.4602	67.6	196.2					2.7	24.0	8.4		5	46.9	10.2				+16
27 Lard oil	*30.5	0.919	1.4615	58.6	194.6					1.3	28.3	11.9		2.7	47.5	6				+17
28 Neatsfoot oil		0.910 ^{25/25}	1.464 ²⁵	69-76	190-199						17-18	2-3			74-76					
29 Tallow, beef				49.5	197					6.3	27.4	14.1			49.6	2.5				
30 Tallow, mutton	*42.0	0.945	1.4565	40	194					4.6	24.6	30.5			36.0	4.3				
Marine-animal Fats and Oils																				
31 Cod liver oil (<i>Gadus morrhua</i>)		0.925 ²⁵	1.481 ²⁵	165	186					5.8	8.4	0.6		20.0	29.1 ¹⁸			25.4	9.6	
32 Herring oil (<i>Clupea harengus</i>)		0.900 ⁶⁰	1.4610 ⁶⁰	140	192					7.3	13.0	Trace		4.9						
33 Menhaden oil (<i>Brevoortia tyrannus</i>)		0.903 ⁶⁰	1.4645 ⁶⁰	170	191					5.9	16.3	0.6	0.6	15.5						
34 Sardine oil (<i>Sardinops caerulea</i>)		0.905 ⁶⁰	1.4660 ⁶⁰	185	191					5.1	14.6	3.2		11.8	17.8 ¹⁸		20.7	30.1	23.2	+19
35 Sperm oil, body (<i>Physeter macrocephalus</i>)				76-88	122-130				1	5	6.5			26.5	37	19				+21
36 Sperm oil, head (<i>P. macrocephalus</i>)				70	140-144			3.5	16	14	8	2		15	17	6.5				+22
37 Whale oil (<i>Balaena mysticetus</i>)		0.892 ⁶⁰	1.460 ⁶⁰	120	195				0.2	9.3	15.6	2.8		14.4	35.2			13.6	5.9	+23

/1/ Underlined superscripts indicate temperature at which density was determined, or, for specific gravity, the temperature of measurement referred to that of water at the indicated temperature; where no superscript appears, the sp. gr. is that calculated to 15°C referred to water at 15°C. /2/ Underlined superscripts indicate temperature of measurement, if other than 40°C. /3/ Contains 87% ricinoleic acid. /4/ Includes behenic and lignoceric acid. /5/ Behenic, 0.2. /6/ Calculated from reported range. /7/ % by weight. /8/ Behenic, 1.1; lignoceric, 1.0; erucic, 51.0. /9/ Includes behenic acid. /10/ Licanic, 82.5. /11/ Behenic, 3.1; lignoceric, 1.1. /12/ Erucic, 50. /13/ C₁₄ monoethenoic, 0.1. /14/ Eleostearic, 90.7. /15/ Butyric, 3.6; decenoic, 0.1; C₁₂ monoethenoic, 0.1; C₁₄ monoethenoic, 0.9; gadoleic plus erucic, 1.4. /16/ Gadoleic plus erucic, 2.5. /17/ C₁₄ monoethenoic, 0.2; gadoleic plus erucic, 2.1. /18/ Oleic plus linoleic. /19/ Behenic, 0.8. /20/ C₁₄ monoethenoic, trace; C₁₄ polyethenoic, 15.4. /21/ C₁₄ monoethenoic, 4; gadoleic, 19. /22/ C₁₂ monoethenoic, 4; C₁₄ monoethenoic, 14; gadoleic, 6.5. /23/ C₁₄ monoethenoic, 2.5; C₂₄ polyethenoic, 0.2.

13. WAXES: PHYSICAL AND CHEMICAL CHARACTERISTICS

Wax	Melting Point °C	Refractive Index n_D^{20}	Specific Gravity or Density* 150/150°C ²	Iodine Value	Acid Value	Saponifi- cation Number
1 Alcocer	67-79	1.455-1.463 ⁸⁵	0.982-0.986* ¹⁵	14.4-20.4	12.7-18.1	35-86
2 Bamboo leaf	79-80		0.961* ²⁵	7.8 ³	14.5	43.4
3 Bayberry (Myrtle)	41-53	1.436-1.446 ⁸⁰	0.981-0.991* ¹⁵	1.0-3.9	2.5-4.5	205-217
4 Beeswax, crude	62-67	1.439-1.453 ⁸⁰	0.927-0.970	6.8-16.4 ⁴	16-25	85-100
5 Beeswax, white, U.S.P.	61-70	1.447-1.465 ⁶⁵	0.959-0.975* ^{15.5}	7-11	17-24	85-109
6 Beeswax, yellow	62-65	1.442-1.449 ⁶⁵	0.923-0.970	3.4-11	19-22	85-106
7 Candelilla	70-75	1.454-1.463 ⁸⁵	0.945-0.996	5.2-32.8	15-25	46.7-59.7
8 Caranday	80-85		0.990 ²⁵	8.0-8.9	5-9.5	64.5-78.5
9 Carnauba	82-85	1.467-1.472 ⁴⁰	0.990-1.001	7.2-13	6-15	65-90
10 Castor oil, hydrogenated	83-88		0.980-0.990* ²⁰	2.5-8.5	1-5	83-88
11 Chinese insect	80.5-84	1.4566-1.4568 ⁴⁰	0.932-0.970	1.4	0.2-1.5	70-93
12 Cotton	70-79		0.957-0.998 ²⁵	11-24.5	21-32	109-180
13 Cranberry	194-218		0.970-1.010* ¹⁵	44.2-57.4	42.1-69.3	85-134
14 Douglasfir	61-63		1.050 ²⁰	27.8-62.5	58.6-80.1	160-210
15 Esparto	67.5-81		0.987-0.989	18-22	22.7-23.9	69.8-79.3
16 Fiber	61-80.5		0.968-0.988	11-23	10.6-34	61-79
17 Flax	65-75		0.908-0.985	25-35	12-25	65-85
18 Ghedda	60.4-66.4	1.440 ⁸⁰	0.956-0.973	4.8-11.4 ⁵	3.5-10.5	86-130
19 Japan	48.5-54.5		0.975-0.993	4.5-12.8	6-20	206-237
20 Jojoba	11.2-11.8	1.465 ²⁵	0.864-0.899	81.7-83.4 ⁴	0.23-0.57	99.2-95.0
21 Madagascar	88.0			3.2-5.9	17.7-28.0	140-159
22 Montan, crude	73-82		1.01-1.02* ²⁵	14-18	40-60	90-110
23 Montan, refined	80-86		1.01-1.03* ²⁵	10-14	40-60	90-110
24 Ouricury	81-86		0.998-1.069	6.2-23.8	12-20	80-100
25 Ozocerite, refined	73-75		0.907-0.920			
26 Palm	74-86		0.991-1.045* ¹⁵	8.9-16.9 ⁴	5.0-10.6	64.5-104
27 Paraffin, American	49-63	1.422-1.448 ⁸⁰	0.897-0.915* ¹⁴			
28 Rice bran	75-83			8-19.4	15-17	57-104
29 Shellac	79-82		0.971-0.980	1.3-8.8 ³	0-2 ⁰	37-50 ⁷
30 Sisal hemp	74-81		1.007-1.010	22.3-33.3 ⁴	16-22.2	56-86.3
31 Sorghum	77-82			15.7-20.9	10-16	16-44
32 Spermaceti	42-50	1.440 ⁷⁰	0.905-0.960	3.0-5.9	0-6.0	108-135
33 Sperm, body	3-46	1.462 ³⁰	0.880-0.883	81-84	1.2	123-133
34 Sugarcane, crude	52-70		0.961-0.998 ²⁵	10-40	8-45	50-120
35 Sugarcane, cuticle	74-81.5			8-15.6	7-24	24-57
36 Sugarcane, commercial	76-82	1.4435 ⁹⁰	0.983 ²⁵	8-20	8-23	55-106
37 Wool, refined	36-55	1.478-1.482 ⁴⁰	0.904-0.945	15-47 ³	5-22	82-140

/1/ Superscripts indicate temperature at which measurement was made. /2/ For specific gravity, superscripts indicate temperature of measurement referred to that of water at the indicated temperature; where no superscript appears, the sp.gr. is that calculated to 15°C referred to water at 15°C. For density, superscripts indicate temperature at which determination was made. /3/ Wijs test. /4/ Hanus test. /5/ Hubl test. /6/ A range of 12-24.3 has been reported. /7/ A range of 64-126 has been reported.

14. PHOSPHATIDES, CEREBROSIDES, AND RELATED LIPIDS: PHYSICAL AND CHEMICAL CHARACTERISTICS

Lipid	Formula	Melting Point °C	Specific Rotation ¹ [α] _D	Iodine Value	Solubility ¹
1 Phosphatides					
2 Lecithins	C ₁₀ H ₂₀ NPO ₉ RR'		5.5-6.0 in chl.	33-127	v.s. al., eth., chl., bz., pet. eth., c. tet., c. disf.; i. actn., me. acet., par.
3 Lysolecithin	C ₉ H ₂₁ NPO ₈ R	100	-2.6 in chl.		v.s. al., eth., chl., pyr.; i. w., actn.
4 Cephalin (phosphatidyl-ethanolamine)	C ₇ H ₁₂ NPO ₈ RR'	174	13.6 in pet. eth.	40-80	v.s. chl., bz., pet. eth., c. disf., ac.a.; i. al., eth., acetn.
5 Phosphatidic acids	C ₅ H ₇ PO ₈ RR'				v.s. eth., actn., m. f. solv.; sl. s. w.
6 Cardiolipin	C ₅ H ₇ PO ₈ RR' (?)		5.8 in al.	99.8-126	v.s. al., actn., m. f. solv.; i. w.
7 Sphingomyelins	C ₄₇ H ₉₇ N ₂ PO ₇	196-198	13.8 in pyr.	30.7	sl. s. al., pyr.; i. eth., actn.
8 Sphingosine	C ₁₈ H ₃₇ NO ₂				v.s. al., actn.; sl. s. eth., pet. eth.; i. w.
9 Dihydrosphingosine	C ₁₈ H ₃₉ NO ₂	60-61			
10 Lignoceryl sphingosine	C ₄₂ H ₈₃ NO ₃	156-157			
11 Plasmalogens	C ₅ H ₁₂ NPO ₆ R				v.s. eth., actn.
12 Cerebrosides					v.s. chl., aq. KOH; sl. s. al., eth., pet. eth., actn.; i. w.
13 Cerasine	C ₄₈ H ₉₃ NO ₈	180-187	-2.5 to -9 in pyr.	31.3	v.s. pyr.; sl. s. al., chl., bz., e. acet., ac. a., actn.; i. eth., pet. eth., w.
14 Phrenosine	C ₄₉ H ₉₄ NO ₉	212	3.7 in pyr.	30.7	v.s. pyr.; sl. s. al., chl., bz., e. acet. ac. a., actn.; i. eth., pet. eth., w.
15 Nervone	C ₄₈ H ₉₁ NO ₈	180	-4.3 in pyr.	62.7	v.s. chl., bz., e. acet., ac. a., actn., pyr.; sl. s. al.; i. eth., pet. eth., w.
16 Cerebronyl-N-sphingosine	C ₄₂ H ₈₃ NO ₄	83-84		38.8	v.s. al., eth., actn.; i. w.
17 Dihydropsychosine	C ₂₄ H ₄₉ NO ₇				v.s. al., actn.; i. eth., pet. eth., w.
18 Ganglioside	C ₆₄ H ₁₁₈ N ₂ O ₂₆		-2.8 in pyr.		v.s. mixt. of chl. or bz. with al.; sl. s. al.; i. eth., e. acet., actn.
19 Psychosine	C ₂₆ H ₄₇ NO ₇	215			v.s. al.; i. eth., pet. eth.

/1/ ac. a.=acetic acid; actn.=acetone; al.=alcohol; aq. KOH=aqueous KOH; bz.=benzene; c. disf.=carbon disulfide; c. tet.=carbon tetrachloride; chl.=chloroform; e. acet.=ethyl acetate; eth.=ether; i.=insoluble; me. acet.=methyl acetate; m. f. solv.=most fat solvents; par.=paraldehyde; pet.=petroleum; pyr.=pyridine; sl.=slightly; s.=soluble; v.=very; w.=water.

15. STEROLS: PHYSICAL AND CHEMICAL CHARACTERISTICS

Part I: ANIMAL STEROLS (ZOOSTEROLS)

Common Name	Systematic Name ¹	Empirical Formula	Melting Point °C	Specific Rotation ² [α] _D	Source
1 Vertebrate Sterols					
2 Cholesterol ³	Δ ⁵ -Cholesten-3β-ol	C ₂₇ H ₄₆ O	149	-39	All animal cells; spinal cord; wool grease.
3 7-Dehydrocholesterol ⁴	Δ ^{5,7} -Cholestadien-3β-ol	C ₂₇ H ₄₄ O	148	-114	Cholesterol; skin of swine; snail.
4 7α-Hydroxycholesterol	Δ ⁵ -Cholestene-3β, 7α-diol	C ₂₇ H ₄₆ O ₂	157	-88	Sclerotic aorta; serum (pregnant mare).
5 7β-Hydroxycholesterol	Δ ⁵ -Cholestene-3β, 7β-diol	C ₂₇ H ₄₆ O ₂	178	+7.2	Liver (cattle; swine); serum (pregnant mare).
6 7-Ketcholesterol	Δ ⁵ -Cholesten-3β-ol-7-one	C ₂₇ H ₄₄ O ₂	157	-104	Testes (cattle; swine).
7 Dicholesteryl ether		C ₅₄ H ₉₀ O	196	-38	Spinal cord.
8	Δ ^{3,5} -Cholestadien-7-one	C ₂₇ H ₄₂ O	112	-305	Testes (swine); sclerotic aorta; spleen (swine).
9 Cholestanol ³	Δ ^{4,6} -Cholestadien-3-one	C ₂₇ H ₄₂ O	80	+35	Sclerotic aorta; spleen (swine).
10	Cholestan-3β-ol	C ₂₇ H ₄₈ O	142	+24	Cholesterol; sclerotic aorta.
11	Cholestane-3,6-dione	C ₂₇ H ₄₄ O ₂	175		Testes (swine).
12	Cholestan-3β-ol-6-one	C ₂₇ H ₄₆ O ₂	143		Spleen (swine).
13	Cholestane-3β, 5α, 6β-triol	C ₂₇ H ₄₈ O ₃	239	+3.2	Liver (cattle); testes (swine); sclerotic aorta.
14	Cholestane-3β, 5α-diol-6-one	C ₂₇ H ₄₆ O ₃	225		Cholesterol; liver (swine).
15	Δ ⁴ -Cholesten-3-one	C ₂₇ H ₄₄ O	81	+89	Feces, hypophysis, testes (swine).
16 Coprostanol	Δ ⁴ -Cholestene-3β, 6β-diol	C ₂₇ H ₄₆ O ₂	258	+9.0	Spleen (swine).
17 Epiprostanol	Coprostan-3β-ol	C ₂₇ H ₄₈ O	101	+28	Feces.
18	Coprostan-3α-ol	C ₂₇ H ₄₈ O	117	+32	Feces; ambergris.
19 Lathosterol ³	Coprostan-3-one	C ₂₇ H ₄₆ O	63	+36	Ambergris.
	Δ ⁷ -Cholesten-3β-ol	C ₂₇ H ₄₆ O	122	+5.7	Skin; cholesterol.
20 Invertebrate Sterols					
21 Aptostanol		C ₂₈ H ₅₀ O	135	+22	Sponge.
22 Chalinasterol ⁵	Δ ^{5,22} -24-iso-Ergostadien-3β-ol	C ₂₈ H ₄₆ O	144	-42	Sponge; oyster.
23 Clionasterol	Δ ⁵ -24-iso-Stigmastien-3β-ol(?)	C ₂₉ H ₅₀ O	138	-37	Sponge.
24 Corbisterol	Δ ^{5,7,22} -Stigmastadien-3β-ol	C ₂₉ H ₄₆ O	151	-106	Corbicula leana.
25 Haliconasterol		C ₂₈ H ₄₈ O	141	-41.5	Sponge.
26 Neospongosterol	Δ ²² -24-iso-Ergosten-3β-ol	C ₂₈ H ₄₈ O	153	+10	Sponge.
27 Palysterol		C ₂₉ H ₅₀ O	140	-47	Sea anemone.
28 Poriferasterol	Δ ^{5,22} -24-iso-Stigmastadien-3β-ol	C ₂₉ H ₄₈ O	156	-49	Sponge.

/1/ The numbers after the symbol Δ indicate the position of double bonds in the basic cyclopentenoperhydrophenanthrene ring. /2/ Chloroform solvent for most determinations. /3/ Also isolated from invertebrates. /4/ Provitamin D₃. /5/ Possibly identical with ostreasterol.

Part II: PLANT STEROLS (PHYTOSTEROLS)

Common Name	Systematic Name ¹	Empirical Formula	Melting Point °C	Specific Rotation ² [α] _D	Source
1 Δ ⁵ -Avenasterol	Δ ^{5,11} (?) -Stigmastadien-3β-ol	C ₂₉ H ₄₈ O	137	-37.6	Oats.
2 Δ ⁷ -Avenasterol	Δ ^{7,11} (?) -Stigmastadien-3β-ol	C ₂₉ H ₄₈ O	145	+8.8	Oats.
3 Brassicasterol	Δ ⁵ -24-iso-Ergosten-3β-ol	C ₂₈ H ₄₆ O	148	-64	Rapeseed; mussel.
4 Campesterol	Δ ⁵ -24-iso-stigmastien-3β-ol	C ₂₈ H ₄₈ O	158	-33	Rapeseed; soybean; wheat germ.
5 Ergostanol	Ergostan-3β-ol	C ₂₈ H ₅₀ O	143	+16	
6 β-Sitosterol	Δ ⁵ -Stigmastien-3β-ol	C ₂₉ H ₅₀ O	140	-36	Cottonseed; calycanthus seed; cinchona bark; wheat germ; rubber.
7 γ-Sitosterol	Δ ⁵ -24-iso-Stigmastien-3β-ol	C ₂₉ H ₅₀ O	148	-43	Soybean; wheat germ; rye germ.
8 Dihydrositosterol	Stigmastan-3β-ol	C ₂₉ H ₅₂ O	140	+25	Grains.
9 α-Spinasterol	Δ ^{7,22} -Stigmastadien-3β-ol	C ₂₉ H ₄₈ O	175	-2.7	Spinach; senega root; alfalfa; colocynth.
10	Δ ⁷ -Stigmastien-3β-ol	C ₂₉ H ₅₀ O	145	+9	Wheat germ.
11 Stigmasterol	Δ ^{5,22} -Stigmastadien-3β-ol	C ₂₉ H ₄₈ O	170	-51	Calabar bean; soybean.
12 Mycosterols					
13 Ascosterol	Δ ^{8,23} (?) -Ergostadien-3β-ol	C ₂₈ H ₄₆ O	147	+45	Yeast.
14 Cerevisterol	Δ ^{7,22} -Ergostadiene-3β, 5α, 6β-triol	C ₂₈ H ₄₆ O ₃	254	-79	Yeast; ergot.
15 Chondrillasterol		C ₂₉ H ₄₈ O	168	-1.1	Green algae; sponge.
16 Episterol	Δ ^{7,24} (28?) -Ergostadien-3β-ol	C ₂₈ H ₄₆ O	151	-5	Yeast.
17 Ergosterol ³	Δ ^{5,7,22} -Ergostatrien-3β-ol	C ₂₈ H ₄₄ O	165	-130	Ergot; yeast; Aspergillus niger.
18 Dehydroergosterol	Δ ^{5,7,9} (11), 22-Ergostatetraen-3β-ol	C ₂₈ H ₄₂ O	146	+149	Yeast; ergot.
19 5-Dihydroergosterol	Δ ^{7,22} -Ergostadien-3β-ol	C ₂₈ H ₄₆ O	174	-20	Yeast.
20 Fecosterol	Δ ^{8,24} (28?) -Ergostadien-3β-ol	C ₂₈ H ₄₆ O	162	+42	Yeast.
21 Fucosterol	Δ ^{5,24} (28)-Stigmastadien-3β-ol	C ₂₉ H ₄₈ O	124	-38	Brown algae.
22 Fungisterol	Δ ⁷ -Ergosten-3β-ol	C ₂₈ H ₄₈ O	148	-0.2	Ergot.
23 Zymosterol	Δ ^{8,24} -Cholestadien-3β-ol	C ₂₇ H ₄₄ O	108	+47	Yeast.

/1/ The numbers after the symbol Δ indicate the position of double bonds in the basic cyclopentenoperhydrophenanthrene ring. /2/ Chloroform solvent for most determinations. /3/ Provitamin D₂.

16. BILE ACIDS: PHYSICAL AND CHEMICAL CHARACTERISTICS

Part I: 24-CARBON ACIDS¹

	Acid	Empirical Formula	Hydroxyl Groups	Melting Point °C	Specific Rotation [α] _D	Sources
1	Bufodesoxycholic acid ²	C ₂₄ H ₄₀ O ₄				Toad.
2	Chenodesoxycholic acid	C ₂₄ H ₄₀ O ₄	3a, 7a	140	+11	Man, coypu, guinea pig, ox, sheep, chicken, duck, goose, turkey, fish.
3	Cholic acid ³	C ₂₄ H ₄₀ O ₅	3a, 7a, 12a	196-198	+37	Man, antelope, bear, goat, ox, sheep, other mammals, duck, turkey, reptiles, salamander, fish.
4	Desoxycholic acid	C ₂₄ H ₄₀ O ₄	3a, 12a	176-177	+53	Man, antelope, deer, dog, goat, ox, rabbit, other mammals, salamander.
5	3a, 12a-Dihydroxy-7-keto-cholanic acid	C ₂₄ H ₃₈ O ₅	3a, 12a	263-264		Ox, snake.
6	7a, 12a-Dihydroxy-3-keto-cholanic acid	C ₂₄ H ₃₈ O ₅	7a, 12a	181-182, ethyl ester		Ox.
7	3a-Hydroxy-Δ ⁸ (14)-cholanic acid	C ₂₄ H ₃₈ O ₃	3a	160	+71	Chicken.
8	3a-Hydroxy-6-ketoallo-cholanic acid	C ₂₄ H ₃₈ O ₄	3a	194		Swine.
9	3a-Hydroxy-7-ketocholanic acid ("nutriacholic acid")	C ₂₄ H ₃₈ O ₄	3a	201-203	-27	Coypu, guinea pig.
10	3a-Hydroxy-12-ketocholanic acid	C ₂₄ H ₃₈ O ₄	3a	164-165	+110	Ox.
11	"α"-Hyodesoxycholic acid	C ₂₄ H ₄₀ O ₄	3a, 6a	196-197	+8	Boar, swine.
12	"β"-Hyodesoxycholic acid	C ₂₄ H ₄₀ O ₄	3β, 6a	189-190	+5	Swine.
13	3-Keto-Δ ^{4,6} -choladienic acid	C ₂₄ H ₃₄ O ₃		150-152		Chicken.
14	"α"-Lagodesoxycholic acid	C ₂₄ H ₄₀ O ₄	3, 12(?)	156-157	+80	Rabbit.
15	"β"-Lagodesoxycholic acid	C ₂₄ H ₄₀ O ₄		213	+37	Rabbit.
16	Lithocholic acid	C ₂₄ H ₄₀ O ₃	3a	184-186	+32	Man, ox, rabbit.
17	"β"-Phocaecholic acid	C ₂₄ H ₄₀ O ₅	3, 7, 23(?)	222-223	+27	Seal, walrus.
18	Pythocholic acid	C ₂₄ H ₄₀ O ₅	3a, 12, 16 or 15(?)	186-187	+28, methyl ester	Snake (Boidae)
19	Ursodesoxycholic acid	C ₂₄ H ₄₀ O ₄	3a, 7β	203	+57	Coypu, bear.

/1/ Derivatives of cholanic acid, possibly excluding Items 1 and 15 (unknown structure) and Item 8 (possible allomerization product). /2/ Not crystallized. /3/ Conjugates with glycine and taurine; glycocholic and taurocholic acids are bile acids most commonly found in man.

Part II: 27-AND 28-CARBON ACIDS¹

	Acid	Empirical Formula	Hydroxyl Groups	Melting Point °C	Specific Rotation [α] _D	Sources
1	Acid (unnamed)	C ₂₇₋₂₈ H ₄₆₋₄₈ O ₆		255		Shark.
2	Sterocholic acid	C ₂₈ H ₄₆ O ₄		256		Ox.
3	Tetrahydroxyisosterocholanic acid	C ₂₇₋₂₈ H ₄₆₋₄₈ O ₆		205		Turtle.
4	Tetrahydroxynorsterocholanic acid	C ₂₇ H ₄₆ O ₆	3a, 6a, 12, 24(?)	212-214	+27	Chicken, fish.
5	Tetrahydroxysterocholanic acid	C ₂₇₋₂₈ H ₄₆₋₄₈ O ₆	3a, 7a, 12a	150		Tortoise, turtle.
6	Trihydroxybufoisosterocholanic acid	C ₂₈ H ₄₀ O ₅	3a, 7a, 12a	227	+47	Toad.
7	Trihydroxybufosterocholanic acid	C ₂₈ H ₄₀ O ₅	3a, 7a, 12a	160	-13	Toad.
8	Trihydroxycoprostan-26-oic acid (originally "α"-trihydroxybisnorsterocholanic acid)	C ₂₇ H ₄₆ O ₅	3a, 7a, 12a	172	+22	Crocodile, frog.
9	Trihydroxycoprostan-27-oic acid (originally "β"-trihydroxybisnorsterocholanic acid)	C ₂₇ H ₄₆ O ₅	3a, 7a, 12a	195-196		Frog.
10	Varanic acid	C ₂₇ H ₄₆ O ₆		120		Lizard.

/1/ Only Items 8 and 9 are of completely determined structure.

17. PROTEINS: PHYSICAL AND CHEMICAL CHARACTERISTICS

Protein	Source	Unit Cell Dimensions (Å units), Space Group ¹				Molecular Weight ²		Sedimentation ³ Constant	Partial Specific Volume ⁴	Protein Crystal Density ⁵	Isoelectric pH ⁶
		a	b	c	β	MW	Method				
1 Actin, G-	Rabbit muscle					80,000	l	3.7			4.5
2 Adrenocorticotrophic hormone	Sheep pituitary					20,000	sd	2.0	0.75 ⁷		4.6-4.7(0.1)
3 Aldolase	Rabbit muscle					147,000	sd(?)	7.9	0.740		8.5(0.0)
4 Amandin	Almond					208,000	e	11.4	0.746		
5 Amylase, α	Barley malt					60,000	o				6
6 Amylase, β	Sweetpotato					150,000	sd	8.9	0.749 ⁷		4.79(0.1)
7 Antitoxin, diphtheria	Horse plasma					180,000	sd	7.2	0.745 ⁷		6.0
8 Bence-Jones	Human urine ⁸					36,000 ⁹	e;sd	3.55	0.749		4.3-4.7
9 Bushy stunt virus	Tomato ⁸	386				10,800,000	x	132	0.739		4.11(0.02)
		I (cubic)									
10 Carbonic anhydrase	Beef blood					30,000	sd	2.8	0.749 ⁷		5.3(0.1)
11 Carboxypeptidase	Beef pancreas					33,000 ¹⁰	sd;vd	3.07	0.75 ⁷		6.0(0.2)
12 Cardiotoxin	Cobra venom					46,000	d		0.75 ⁷		
13 Casein (caseinogen)	Cow milk					33,600	o	10.4	0.728		4.6
14 Catalase	Human blood					220,000	s;a	11.2	0.73 ⁷		
15 Chorionic gonadotropin	Human urine ¹¹					100,000	sd	4.3	0.76		
16 Chymotrypsin, α	Beef pancreas	49.6	67.8	66.5	102 ⁹	22,500	sd;sv	2.5	0.73		8.1(0.1)
		P2 ₁									
17 Chymotrypsinogen, α	Beef pancreas					22,500	sd;sv	2.5	0.72		9.5(0.01)
18 Colostrum globulin, immune	Cow colostrum					175,000 ¹²	d	7			5.85(0.1)
19 Conalbumin	Chicken egg white					74,000	a				6.8(0.1)
20 Concanavalin A	Jack bean					96,000	sd	6.0	0.73		
21 Crotoxin	Rattlesnake venom					30,000	e;sd	3.1	0.704		4.7(0.1)
22 Cytochrome-c	Beef or horse heart					16,000	sd	1.9	0.707		10.65 ¹³ (0.1)
23 Edestin	Hemp seed					310,000	sd	12.8	0.745	1.29-1.32	5.5 ¹⁴
24 Excelsin	Brazil nut	86		208.2 ¹⁵		295,000	sd	11.8	0.743	1.285	
		R3									
25 Fetuin	Fetal calf blood					50,000	sd	3.1-3.4	0.70		3.5(0.2)
26 Fibrinogen	Human blood					500,000 ¹⁶	o;sv	9			5.4(0.1)
27 Gelatin	Collagenous tissues					Variable ¹⁷	o				4.9(0.01)
28 Gliadin	Wheat					27,000	e	2.1	0.71		6.5 ¹⁴
29 Globin	Horse blood					37,000	sd	2.5	0.749		7.5(0.1) ¹⁸
30 Globulin, α	Barley					26,000	sd	2.5	0.72		5.0(0.1)
31 Globulin, γ	Barley					170,000	sd	8.3			5.7(0.1)
32 Gluten	Wheat					39,000 ¹⁹	e	2.5	0.700		7
33 Growth hormone	Beef pituitary					47,000 ²⁰	a;sd	3.6	0.76		6.85(0.1)
34 Hemocyanin	Helix pomatia					8,900,000	sd	103	0.738		5.05(0.02)
35 Hemoglobin	Human blood	109	63.2	54.4	111 ⁹	66,700 ²²	sd	4.5	0.749	1.16	6.87(0.1)
		C2 ₂₁									
36 Hexokinase	Baker's yeast					97,000	sd	3.1	0.740 ⁷		4.5-4.8(0.02M) ²³
37 Insulin	Beef pancreas	83		34		36,000	o;sd	3.5	0.749	1.28	5.2(0.033)
		R3 ²⁴									
38 Lactalbumin, α	Cow milk					17,500	sd	1.9			
39 Lactogenic hormone	Beef, sheep pituitary					26,500	o				5.7(0.05)
40 Lactoglobulin, β	Cow milk	69.29	70.42	156.47		35,400	x	3.12	0.751	1.146	5.1(0.1)
		P2 ₁ 2 ₁ 2 ₁									
41 Lactoglobulin, immune	Cow milk					180,000	sd	7			5.8(0.1)
42 Lysozyme chloride	Chicken egg white	79.1		37.9		13,900	x	2.1	0.722	1.233	11.35(0.1)
		P4 ₁ 2 ₁									
43 Metakentrin	Sheep pituitary					40,000	o;a	3.6			4.6(0.1)
44 Myosin	Rabbit muscle					850,000	sd;o	7.1			5.4(0.1-0.5)
45 Ovalbumin	Chicken egg white					44,000	sd	3.55	0.749	1.24-1.27	4.58(0.1)
46 Pepsin	Hog gastric mucosa	67.9		292		36,000	x	3.3			2.75-3.0
		C6 ₁₂									
47 Relaxin	Pregnant sow ovary					9,000	a;s				
48 Ribonuclease	Beef pancreas	30.90	38.80	54.06	106 ⁹	13,400	x	1.85	0.709	1.220	7.8(0.055)
		P2 ₁									
49 Ricin	Castor bean					80,000	sd	4.8	0.75 ⁷		5.2-5.5
50 Salmine	Salmon testes					7,000	a	<1			12
51 Serum albumin	Human blood	178 ²⁵	54 ²⁵	166 ²⁵	91 ⁰	65,600	x	4.6	0.733	1.145	4.9
		C2									
52 Serum globulin, α_1	Human blood					200,000	sv	5.0	0.841		
53 Serum globulin, β_1	Human blood					90,000	sv	5.5	0.725		
54 Serum globulin, γ	Human blood					160,000	sv	7.2	0.739		5.7(0.1) ²⁶
55 Serum globulin, γ_1 , anti-pneumococcus	Human blood					190,000	sd	7.4	0.745 ⁷		5.6(0.1) ²⁷
56 Thymus nucleohistone	Calf thymus					2,000,000	e;sd	31.0	0.658		
57 Thyroglobulin	Hog thyroid					700,000	sd	19.2	0.72		4.58(0.02)
58 Tobacco mosaic virus	Tobacco leaves ⁸					40,000,000	x	185	0.72		3.49(0.02)
59 Toxin, botulinum, type A	Cl. botulinum					900,000	sd	17	0.75		
60 Toxin, botulinum, type B	Cl. botulinum					60,000	d				
61 Toxin, diphtheria	C. diphtheriae					74,000	sd	4.6	0.736		4.1(0.005) ²³
62 Toxin, tetanus	Cl. tetani					67,000	a;s	4.5			
63 Trypsin	Beef pancreas					20,700	a				10.8(0.03M)
64 Trypsin inhibitor	Beef pancreas	111		122		6,000	o				
		C6 ₃₂									
65 Tuberculin protein	M. tuberculosis					32,000	sd	3.3			4.3(0.03)
66 Tyrosinase	Ps. campestris					100,000	sd	6.4	0.75 ⁷		<5
67 Urease	Jack bean					480,000	sd	18.6	0.73		5.0(0.012) ¹⁴
68 Yellow enzyme, "old"	Brewer's yeast					80,000	sd;e	5.8	0.731		5.22(0.02)
69 Zein	Maize					40,000	sd	1.9	0.73 ⁷		

/1/ From X-ray data. Wet preparation, unless otherwise noted. /2/ The code describing the method used is: a=chemical analysis or combining ratio; d=diffusion constant; e=sedimentation equilibrium; l=light scattering; o=osmotic pressure; s=sedimentation velocity; v=intrinsic viscosity; x=X-ray diffraction. /3/ Specific sedimentation velocity in units of 10^{-13} . /4/ Cubic centimeters increase in volume of solution per gram of protein dissolved.

/5/ Grams per cubic centimeter, wet. /6/ pH at which protein does not move in an electric field. The ionic strength is given in parentheses. /7/ Assumed value. /8/ Pathological. /9/ 35,000-37,000. /10/ 32,000-34,000. /11/ During pregnancy. /12/ 160,000-190,000. /13/ At 0°C for the oxidized (ferri) form. /14/ Based on solubility minimum. /15/ Dry. /16/ 400,000-580,000. /17/ 5,000-400,000. /18/ For human globin. /19/ To 4,600,000. /20/ 44,000-49,000. /21/ Met-co-oxyhemoglobin I (horse). /22/ Same value also for oxy-, met-, and carboxyhemoglobin. /23/ By cataphoresis.

/24/ Crystalline modification of insulin (Scott-Zn) with molecular weight of 5734. /25/ Dimensions of a pseudo-orthogonal unit cell with all faces centered. /26/ Depends on fraction employed. /27/ Hyperimmune horse blood.

18. PLASMA PROTEINS, ELECTROPHORETIC ANALYSIS: MAMMALS AND BIRDS

Veronal-citrate buffer, pH 8.6; ionic strength 0.1. Values are mobilities ($m = \text{sq cm per sec per volt} \times 10^5$) and percentages of total protein.

Veronal-citrate buffer, pH 8.6; ionic strength 0.1. Values are mobilities (m=sq cm per sec per volt x 10 ⁻⁷) and percentages of total protein.																	
Species		Component															
		Fast ¹		Albumin		Globulin											
						α_1		α_2		α_3		β		ϕ		γ	
		m	%	m	%	m	%	m	%	m	%	m	%	m	%	m	%
1	Man			6.6	59.6	5.4	6.7	4.3	8.8			3.1	11.0	2.3	4.8	1.3	9.1
2	Cat			7.7	41.4	6.3	8.1	5.2	20.2	4.1	4.7	3.4	8.7	2.6	5.2	1.6	12.5
3	Cow			7.0	40.6	5.5	10.7	4.7	8.3			3.7	13.7	2.6	16.3	1.4	11.0
4	Dog			6.8	39.6	5.7	16.9	4.4	8.0			3.3	13.0	2.4	13.3	1.2	9.3
5	Fox			7.5	47.1	6.4	10.2	5.2	7.8					3.2	31.2	1.3	3.9
6	Goat			7.3	49.2	5.6	13.7	4.1	12.7			3.1	3.9	2.5	7.6	1.5	12.9
7	Guinea pig			6.1	54.6	5.4	4.0	4.9	3.7	4.4	15.2	3.0	8.8	2.1	8.1	1.0	5.6
8	Horse	7.9	0.8	7.1	29.8	5.8	8.2	4.8	12.3			3.7	21.9	2.5	15.8	1.4	11.2
9	Mink			4.9	51.5	4.2	11.7	3.8	9.8			3.7	10.3	3.2	5.0	2.2	12.1
10	Monkey	7.4	0.5	6.6	50.0	5.4	5.9	4.8	5.2	4.2	4.7	3.3	16.1	2.2	8.4	1.4	9.0
11	Rabbit			6.8	63.3	5.1	11.5					3.5	13.0	2.4	7.9	1.4	4.3
12	Rat	7.1	1.3	6.1	59.1				15.4					2.7	19.4	1.6	4.8
13	Sheep			6.8	43.7	5.3	9.8	4.3	6.7			3.4	15.0	2.6	9.7	1.6	15.0
14	Swine	7.3	0.4	6.5	39.9	5.2	6.0	4.4	16.3			3.7	8.2	2.8	13.9	1.8	15.2
15	Chicken	7.5	0.6	6.8	40.4	5.4	14.9	4.1	11.3							2.5	32.8
16	Duck	7.6	2.6	6.7	47.8	5.8	21.9	4.9	6.1					3.7	15.5	2.5	6.0
17	Pheasant	6.1	0.4	5.2	58.5	4.2	14.0	3.6	6.5					2.9	16.3	1.7	4.3
18	Pigeon	7.8	3.1	6.4	64.1	5.2	7.2	4.5	4.5					3.3	17.4	1.7	7.7
19	Turkey	6.7	1.0	5.9	51.5	5.0	13.4	4.1	4.3					2.9	21.6	1.7	8.1

/1/ A component on the leading shoulder of the albumin peak.

19. SERUM PROTEINS, ELECTROPHORETIC ANALYSIS: REPTILES, AMPHIBIANS, FISH, AND INVERTEBRATES

Veronal buffer, pH 8.6; ionic strength 0.1. Values are mobilities ($m = \text{sq cm per sec per volt} \times 10^5$) and percentages of total protein.

Species	Component																			
	1		2		3		4		5		6		7		8		9		10	
	m	%	m	%	m	%	m	%	m	%	m	%	m	%	m	%	m	%	m	%
1 Rattlesnake, diamond back	1.7	4.4	2.6	5.9	3.2	6.0	3.7	21.0	4.3	8.7	4.7	3.9	5.3	8.7	5.8	4.0	6.3	4.6	7.3	32.8
2 Rattlesnake, timber	3.4	3.8	4.7	3.5	6.2	19.7	7.4	9.4	8.7	8.8	8.0	13.3	11.0	10.3	12.4	28.4	14.0	2.8		
3 Snake, milk	1.4	1.3	2.0	5.7	2.6	16.4	3.4	11.6	3.8	5.9	4.4	5.8	5.1	11.9	6.5	23.8	7.9	17.6		
4 Snake, water	3.8	16.6	4.1	17.9	5.7	30.7	6.9	5.0	7.6	10.3	8.8	3.5	10.0	6.6	11.7	9.4				
5 Snake, water moccasin	1.0	2.5	1.8	15.8	2.8	18.8	3.9	13.5	4.5	5.4	5.0	5.3	5.7	11.3	6.4	6.4	6.8	5.4	7.4	15.6
6 Turtle, snapping	1.1	5.3	1.8	20.5	3.8	31.5	3.6	16.6	4.5	7.5	5.3	16.2	6.1	2.4						
7 Turtle, soft-shelled	1.4	1.9	2.5	15.5	3.5	11.6	4.4	17.6	5.8	51.8	6.9	1.6								
8 Frog, bull	1.5	8.4	2.3	7.0	3.1	5.5	3.7	5.8	4.3	12.0	4.9	22.4	5.6	16.0	6.5	22.4	7.2	0.5		
9 Bass, rock	2.3	1.3	3.0	5.7	3.6	2.9	4.3	9.3	5.4	24.2	6.1	17.3	7.0	10.7	7.9	27.9	8.8	0.7		
10 Buffalo-fish	1.4	2.5	2.5	25.0	3.1	10.2	3.9	9.7	4.7	17.8	5.4	5.5	6.2	5.5	6.9	23.8				
11 Bullhead	1.8	0.6	3.0	4.7	4.0	8.5	5.4	15.8	6.8	7.3	7.6	9.3	8.7	30.6	10.0	23.2				
12 Carp	2.3	4.1	3.7	8.2	4.7	14.3	5.7	15.0	7.1	21.5	8.6	36.9								
13 Catfish, channel	1.3	2.9	1.8	3.8	2.3	3.2	3.0	6.6	3.9	6.6	4.7	11.2	5.7	20.6	6.5	45.1				
14 Catfish, eel, willow cat	1.7	6.2	2.3	7.8	3.1	4.3	3.7	5.1	4.4	14.1	5.6	32.4	6.7	4.2	7.7	25.9				
15 Perch, yellow	2.5	1.8	2.9	2.6	3.5	7.0	4.4	4.6	5.0	16.6	5.8	8.8	6.5	4.4	7.2	5.2	8.0	7.0	8.7	11.0 ¹
16 Pike, northern	1.9	7.8	2.8	12.2	3.7	6.3	4.3	7.8	5.7	48.2	8.0	13.5	8.7	4.2						
17 Sucker	1.4	1.4	2.1	13.6	3.0	14.2	3.8	12.1	4.9	18.7	5.5	7.6	6.4	31.8	7.4	0.6				
18 Sturgeon, rock	1.7	22.6	2.3	8.5	3.0	10.4	3.6	5.6	4.3	5.3	5.0	18.3	5.6	11.5	6.2	8.9	6.9	7.4	7.4	1.5
19 Trout, lake	1.3	1.4	2.2	3.8	2.7	7.9	3.4	6.5	4.2	8.2	4.9	12.8	6.5	58.4	7.5	1.0				
20 Trout, rainbow	1.3	1.2	2.0	1.6	2.7	3.4	3.1	4.0	4.2	34.7	5.1	6.7	6.3	45.6	7.4	2.8				
21 Whitefish	1.3	0.5	2.7	7.5	3.0	11.7	3.5	12.7	4.1	8.1	4.8	14.6	5.7	12.1	5.9	17.6	7.0	14.7	7.7	0.5
22 Crab, horseshoe	2.0	4.0	4.5	7.5	5.1	10.7	6.1	24.5	6.7	53.3										
23 Snail, land	2.4	2.7	3.5	2.0	4.7	4.8	6.2	7.0	7.1	13.6	7.9	62.3	9.5	7.6						

/1/ Eleventh and twelfth components with m and % of 9.7, 29.8, and 10.8, 1.2, respectively, were also found.

20. PLASMA PROTEINS, PROPERTIES AND REACTIONS: MAN

Protein Component	Electrophoretic Fraction	Interacts with:	General Properties
1 Albumin	Albumin	Fatty acids, bile salts, dyes	Osmotic regulation of blood volume.
2 α_1 -Lipoproteins	α_1 -globulin	Steroids	35% lipid.
3 Antibody euglobulin	γ_1 -globulin	Antigens	Typhoid "O" and other agglutinins.
4 Antibody γ -globulin	γ -globulins	Antigens	Antibodies for pathogenic organisms.
5 Antihemophilic globulin			Necessary for clotting of hemophilic blood.
6 β_1 -Lipoproteins	β_1 -globulin	Steroids	Carrier for vitamins, hormones, triglycerides.
7 Bradykininogen			Bradykinin precursor.
8 Cholinesterase		Tryptic enzymes	
9 Complement components C ₁ , C ₂	α - and β -globulins	Choline esters	
10 Fibrinogen		Antigen-antibody complex	
11 Hypertensinogen	α_2 -globulin	Thrombin	Forms fibrin clot.
12 Isoagglutinins	γ -globulins	Renin	Hypertensin precursor.
13 Peptidase		Incompatible red blood cells	Anti-A, anti-B, anti-Rh agglutinins.
14 Phosphatase, alkaline		L-Leucylglycylglycine	
15 Plasmin		Phosphoric acid monoesters	
16 Plasminogen		Proteins	Digests protein, fibrin clots.
17 Prothrombin		Streptokinase	Enzyme precursor.
18 Siderophilin	β -globulin	Thromboplastin	Enzyme precursor.
19 Thrombin		Fe ⁺⁺⁺	Iron transport.
20 Thyrotropic hormone	α -globulin	Fibrinogen	Catalyzes formation of fibrin clot.
			Influences thyroid activity.

21. ENZYMES: CHEMICAL COMPOSITION

Enzymes listed were either crystalline or electrophoretically homogeneous. Values are grams per 100 grams enzyme.

Enzyme		Elements					Amino Acids																			
		C	H	N	S	P	Other Elements	Alanine	Arginine	Aspartic Acid	Cysteine	Cystine ^{1/2}	Glutamic Acid	Glycine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenyl- alanine	Proline	Serine	Threonine	Tryptophan	Tyrosine	Valine
1	Alcohol dehydrogenase	52.8	6.96	16.54	1.21	Trace	Trace(Fe)																			
2	Aldolase			16.8				8.56	6.33	9.7		1.12	11.4	5.61	4.21	7.87	11.5	9.54	1.17	3.06	5.71	6.57	7.1	2.31	5.31	7.40
3	α-Amylase, human pancreas			15.8	0	0.01																				
4	α-Amylase, human saliva			15.52	0	0.01																				
5	α-Amylase, swine pancreas	49.46	7.18	15.52	1.33	0.05																				
6	α-Amylase, barley malt			13.4		0.01	0.035(Fe)																			
7	β-Amylase, sweetpotato			15.1					6.0		0.79 ¹							4.32							7.0	
8	Carbonic anhydrase			15.9			0.33(Zn)				1.3														4.1	
9	Carboxypeptidase, pancreatic	52.6	7.2	14.4	0.47	0	0.18(Zn)	5.16	5.06	11.7		1.40 ²	10.7	5.06	3.47	7.65	9.41	7.81	0.44	7.16	3.66	10.1	9.21	3.62	10.3	5.58
10	Catalase, horse blood			16.8			0.093(Fe)		8.75	16.5		1.65 ²	10.9		4.17			7.50							6.0	
11	Catalase, horse liver			16.8			0.093(Fe)		8.90	16.5		1.85 ²	10.3		3.86			6.91							5.8	
12	Catalase, human blood			16.7			0.077(Fe)																			
13	α-Chymotrypsin	50.0	7.06	15.5	1.85	0	0.16(Cl)				1.22	3.66			1.26	9.1		1.25				11.2	5.81	2.83		
14	β-Chymotrypsin			16.24	1.56						1.29	3.51			1.22	9.4		1.29				10.6	6.40	2.87		
15	γ-Chymotrypsin			16.00	1.59						1.27	3.59			1.26	8.5		1.28				10.7	6.27	3.09		
16	Chymotrypsinogen	50.6	7.0	15.8	1.9	0	0.17(Cl)		2.82	11.3	1.29	3.30	9.0	5.3	1.23	5.7	10.4	8.0	1.22	3.6	5.9	11.4	11.4	5.57	2.96	10.1
17	Cytochrome - c	52.52	7.76	15.36	1.47	0	0.43(Fe)		5.6 ³			1.4 ³			6.3 ³			30.8 ³						1.4 ³	3.5 ³	
18	Desoxyribonuclease	50.16	6.91	14.88	1.09	0																				
19	Enolase	53.62	7.55	17.34	0.38	0																				
20	D-Glyceraldehyde phosphate dehydrogenase ⁴	52.54	7.51	16.41	1.08	Trace		6.72	5.23	12.4		1.09	6.8	6.03	5.01	9.1	6.78	9.42	2.70	5.55	3.67	7.7	7.2	2.05	4.57	12.0
21	Hexokinase	52.16	7.08	15.62	0.91	0.11																				
22	Lecithinase	50.77	6.41	15.88	4.0																					
23	Lipoxidase																									
24	Lysozyme			18.6	2.53			6.0	12.9	18.2	0	8.0 ²	10.4	6.3	3.6	8.1	11.4	7.8	1.8	4.9	5.1	8.9	0.41	6.2	7.8	
25	Papain			15.5	1.2	0		5.63	7.75	11.3		4.58 ²	12.4	8.41	0.85	6.05	6.10	5.67		3.16	5.11	5.91	3.89	4.68	14.7	8.43
26	Pepsin, cattle	51.7	6.86	14.6	0.94	0.09			1.0	16.0	0.5	1.64	11.9	6.4	0.9	10.8	10.4	0.9	1.7	6.4	5.0	12.2	9.6	2.36	8.5	7.1
27	Pepsin, salmon	51.9	6.48	15.62	1.58	0.03																				
28	Pepsinogen	52.8	6.88	15.9	0.09																					
29	Peptic inhibitor ⁵	48.1	8.07	16.65						31 ³																
30	Peroxidase	47.0	7.35	13.2	0.43		0.13(Fe)		6.91						0.71			4.06						0	0.4 ³	
31	Phospho-enoltrans-phosphorylase, human muscle	53.35	7.30	17.40	1.60	0.06																				
32	Phosphorylase, rabbit muscle			16.5				4.79	11.6	9.3		0.45	13.4	3.8	3.3	6.5	10.5	7.2	2.7	6.2	4.7	3.05	4.24	2.0	5.9	7.3
33	Polypeptidase, yeast			13.5		0.3																				
34	Pyrophosphatase, yeast	54.46	7.36	16.25	0.14	0		4.9	3.3	12.1			9.7	2.9	2.2	8.9	6.0	10.9	1.3	6.2	6.4	3.1	4.8	3.6	6.0	4.1
35	Rennin	51.4	7.19	14.51	1.46	0.04	0.0035(Cu)																			
36	Ribonuclease	48.2	6.2	16.1	1.1	Trace		7.67	4.94	15.0		7.0	12.4	1.64	4.22	2.67	2.02	10.5	4.0	3.51	3.94	11.4	8.90		7.60	7.49
37	Trypsin	50.2	6.6	16.13	1.1	0	2.85(Cl)																	3.65	7.8	
38	Trypsinogen	50.1	6.9	15.3	1.1																					
39	Tryptic inhibitor ⁵ , soybean	51.95	7.16	16.74	0.97	0																		2.2	4.0	
40	Tyrosinase			13.6			0.25(Cu)																			
41	Urease	51.6	7.1	16.0	1.2																					
42	Verdoperoxidase			17.15			0.1(Fe)																			
43	"Yellow enzyme, old"	51.4	7.07	16.27	0.48	0.043			8.25		0.34		7.1	2.75			13.7		5.75					4.86	7.75	

/1/ Cysteine plus cystine. /2/ Cystine. /3/ Per cent of total nitrogen. /4/ Element analysis refers to yeast enzyme; amino acid composition to rabbit muscle enzyme. /5/ Not an enzyme in the strict sense of the term.

22. ENZYMES: PHYSICAL PROPERTIES

Enzyme	Source	Molecular Weight	Isoelectric pH	Solubility ¹ g/100 ml	Absorption Maximum mμ	Optical Rotation ² [α] _D ²⁵	Reaction Velocity Constants				
							Substrate	Temp °C	pH	Turnover Number ³	K _s ⁴ Molarity
1 Alcohol dehydrogenase	Yeast	70,000					Ethanol, DPN	20	8.2	18,000	
2 Aldolase	Rat muscle	147,000	5.7	s. w.			Fructose-1,6-diphosphate	25	7.1	10,100	1.2x10 ⁻³ ⁵
3 α-Amylase	Human saliva		5.0-5.5	0.3 ₂ at pH 8.5			Starch				4.8x10 ⁻³
4 α-Amylase	Human pancreas			0.3 ₂ at pH 8.5							
5 α-Amylase	Swine pancreas	45,000	4.6-5.2	6 ₂ at pH 8.5							
6 α-Amylase	Malt, barley	60,000	5.7	10 ₂ at pH 8.5; s. al. 40%			Starch	25	4.7		0.078%
7 β-Amylase	Sweetpotato	150,000	4.7-4.8								
8 Carbonic anhydrase	Red cells, mammalian	30,000	5.3				CO ₂	0	7.3		9x10 ⁻³
9 Carboxypeptidase	Cattle pancreas	33,000	5.95	i. w.			Benzenesulfonyl glycyl-phenylalanine	25	7.5		1.4x10 ⁻²
10 Catalase	Cattle liver	225,000	5.7	s. w.	405		H ₂ O ₂	25.5	7.0	120,000,000 ⁶	2 ⁷
11 Catalase	Horse liver	225,000	5.4		405		H ₂ O ₂	23-25	6.7	210,000,000 ⁶	3 ⁷
12 Catalase	Human blood	220,000			405		H ₂ O ₂	18	6.8	135,000,000 ⁶	
13 α-Chymotrypsin	Cattle pancreas	22,500	8.1-8.6	v. s. w.		-0.40°/mg N	Benzoyl-L-phenylalanine methyl ester	25	7.8	3,060	
14 α-Chymotrypsinogen	Cattle pancreas	22,500	9.5	sl. s. w.		-0.48°/mg N					
15 Desoxyribonuclease	Cattle pancreas	60,000	5.0	s. w.	280						
16 Diaphorase	Swine heart	70,000			274,359,451		2,6-Dichlorophenol-indophenol		8.5	2,700	1.2x10 ⁻⁴
17 Enolase	Brewers' yeast	66,000 ⁸					2-Phosphoglycerate	20	7.34	6,500	
18 Fumarase	Swine heart	204,000	5.0-5.4				Fumarate	25	7.4		
19 Glutamic dehydrogenase	Cattle liver	1,000,000	4-5	i. w. (low pH)	279		Glutamic acid	Room	7.6	30,000	1.37x10 ⁻³
20 α-Glycerophosphate dehydrogenase	Yeast	120,000	4-7	sl. s. w.	280		Dihydroxyacetone phosphate	22	7	26,500	
21 Hexokinase	Yeast	97,000	4.5-4.8	s. w.			Glucose	30	8.0	13,000 ⁹	1.6x10 ⁻⁴
22 Lactic dehydrogenase	Rat liver	126,000	6.3	s. w.; dil. salt sol.			Lactate, DPN	25	7.0	12,800	
23 Lactoperoxidase	Milk	82,000	8.05	s. dil. salt sol.	280,412		H ₂ O ₂	25	7.0	1,500	10 ⁻⁸
24 Lipase	Swine pancreas						Methyl butyrate	25-28	7.0		9x10 ⁻²
25 Lipoxidase	Soybean	102,400	5.4	s. dil. salt sol.	280		Linoleate	20	9.0	21,600	1.35x10 ⁻³
26 Lysozyme	Egg	13,900	11.35	sl. s. w.							
27 N ₂ fixing system	Azotobacter						Nitrogen	32	7.0	18	2x10 ⁻² ¹⁰
28 Papain	Papaya latex	27,000 ⁸	9-9.5	s. w., al. 70%							
29 Pepsin	Cattle	36,000	2.7	s. w.	280	-71°/gram	Carbobenzoxy-L-glutamyl-L-tyrosine ethyl ester	38	4.0	0.18	1.9x10 ⁻³
30 Pepsinogen	Cattle	42,000 ¹¹				-61°/gram					
31 Peroxidase	Horseradish	44,100	7.2				H ₂ O ₂	25	4.1		4.5x10 ⁻⁷ ¹²
32 Phosphoglucosyltransferase	Rabbit muscle				278		Glucose-1-phosphate	30	7.5	16,800	
33 Phosphorylase	Muscle	375,000 ¹³	5.8	s. salt sol.			Glucose-1-phosphate	30	6.7	40,000	2.6x10 ⁻³
34 Pyrophosphatase	Yeast	100,000	4.75	s. w.							
35 Pyruvate kinase	Muscle						Phosphopyruvate	20	6.77	6,000	
36 Rennin	Calf gastric juice	40,000	4.5-4.65	sl. s. w.							
37 Ribonuclease	Cattle pancreas	13,400	7.8	s. w.	280	-0.47°(5%)					
38 Trypsin	Cattle pancreas	20,700	10.8	v. s. w.		-0.27°/mg N	Benzoyl-L-arginine ester	25	7.7	1,610	8x10 ⁻⁵
39 Trypsinogen	Cattle pancreas	34,000	9.3								
40 Tyrosinase	Wild mushroom	100,000		i. dil. a., salt sol.	273,330		Tyrosine	25	6.0		8x10 ⁻⁴ ¹⁴
41 Urease	Jack bean meal	480,000	5.0-5.1				Urea	20	7.1	460,000	4x10 ⁻³
42 "Yellow enzyme, old"	Yeast	80,000	5.22								

/1/ Abbreviations: a.=acid; al.=alcohol (ethyl, 95%); dil.=dilute; i.=insoluble; s.=soluble; sl.=slightly; v.=very; w.=water. Underlined superscripts represent temperature at which solubility was determined. /2/ In water at concentration shown at 25°C. /3/ Moles of substrate decomposed by one mole of enzyme per minute. /4/ Michaelis constant. /5/ K_s determined at pH 8.6 and 38°C. /6/ True only under the hypothetical condition that the concentrations of substrate and enzyme are the same and constant. /7/ Ratio of two consecutive reaction constants of enzyme with substrate. No true Michaelis-Menten constant exists. /8/ ±2000. /9/ For glucose. /10/ Expressed in atmospheres. /11/ ±3000. /12/ Range 4.1-5.0x10⁻⁷. /13/ Estimated range 340,000-400,000. /14/ K_s is for tyrosinase from Neurospora sp.

23. ENZYMES: OCCURRENCE AND REACTIONS

Enzyme	Co-factors ¹	Reactions Catalyzed ¹	Conditions Suitable for Enzyme Action ²			Occurrence
			pH	Substrate Concentration	Temp °C	
1 Aconitase	Fe ⁺⁺	Citric acid→cis-aconitic acid→isocitric acid	7.4	0.03 M	25	Tissues; bacteria; yeasts; seeds; leaves.
2 Adenosinetriphosphatase	Ca ⁺⁺	ATP→ADP + PO ₄	7.5	1 mg P/ml	37	Brain; muscle; venoms; potatoes.
3 Aldolase	Co ⁺⁺ , Fe ⁺⁺ , or Zn ⁺⁺	Fructose-1, 6-diphosphate→triosephosphates	9	0.01 M	38	Muscle; E. coli; yeasts; higher plants.
4 Amino tripeptidase		Tripeptide→dipeptide + amino acid	8.0	0.05 M	39	Mucosa; muscle.
5 α-Amylase (animal)	NaCl	Starch or glycogen→dextrins + maltose	7	1%	37	Liver; saliva; urine.
6 α-Amylase (plant)		Starch or glycogen→dextrins + maltose	4.5-5.5	12 mg/ml	30	Bacteria; yeasts; cereals.
7 β-Amylase (animal, plant)		Starch→dextrins + maltose	4-5	12 mg/ml	30	Cereals; soybeans; sweetpotatoes.
8 Amylosucrase		Sucrose→"glycogen" + fructose	5.6	10 mg/ml	23	Bacteria.
9 Apyrase	Ca ⁺⁺	ATP→AMP + 2 phosphate	6.5		30	Liver; muscle; yeasts; tubers.
10 Arginase	Co ⁺⁺ , Mn ⁺⁺	L-Arginine→L-ornithine + urea	9.5	0.66%	38	Liver; bacteria; fungi; seeds; spleen.
11 Asparaginase		L-β-Asparagine→L-aspartic acid + NH ₃	8	0.5 M	40	Liver; mucosa; bacteria; fungi; seeds.
12 Aspartase		L-Aspartic acid→fumaric acid + NH ₃	7-7.5	0.1 M	37	Bacteria; yeasts; leaves.
13 Carbonic anhydrase		H ₂ CO ₃ →CO ₂ + H ₂ O	5-9	0.08 M	15	Erythrocytes; gastric mucosa.
14 Carboxylase, amino acid	Pyridoxal phosphate	Amino acid→amines + CO ₂	4-5.5	0.001 M	30	Liver; kidney; pancreas; bacteria; higher plants.
15 Carboxylase, oxalacetic	Mn ⁺⁺	Oxalacetate→pyruvate + CO ₂	5.0	0.5 mg/L	30	Liver; bacteria; seeds; leaves.
16 Carboxylase, pyruvic	Thiamine pyrophosphate Mg ⁺⁺	Pyruvate→acetaldehyde + CO ₂	6.0	0.15 M	30	Fungi; bacteria; seeds.
17 Carboxylase, succinic		Succinic acid→propionic acid + CO ₂				Bacteria.
18 Carboxypeptidase		Peptide (free COOH)→amino acid + peptide	8.5	6% edestin	25	Pancreas (as zymogen).
19 Catalase		H ₂ O ₂ →H ₂ O + O ₂	6.8	0.01 N	0	Erythrocytes; liver; kidney; bacteria; higher plants.
20 Cellulase		Cellulose→simple sugars				Snails; bacteria; fungi; malt.
21 Chlorophyllase	CaCl ₂	Chlorophyll→chlorophyllide + phytol	5.9	1 mg/ml	25	Bacteria; leaves; stems.
22 Choline acetylase	CoA, ATP	Choline + acetyl CoA→acetylcholine	7			Brain; muscle; bacteria.
23 Chymotrypsin		Proteins→polypeptides + amino acids	7.6	5% casein	38	Pancreas.
24 Conjugase	Ca ⁺⁺	Pteroylglutamate→pterine + glutamic acid	7-8		37	Pancreas; tissues; yeasts; tubers.
25 Dehydrogenase, alcohol	DPN	Ethanol→acetaldehyde	7.8	0.03%	20	Liver; kidney; brain; blood; yeasts; bacteria; higher plants.
26 Dehydrogenase, glucose	DPN or TPN	D-Glucose→D-gluconic acid	7.4	0.2 M	38	Liver.
27 Dehydrogenase, glucose-6-phosphate	TPN	Glucose-6-phosphate→phosphogluconate	7.5	0.02 M	38	Blood; yeasts.
28 Dehydrogenase, glutamic	DPN or TPN	Glutamate→α-ketoglutarate + NH ₃	8.2	0.0001 M	37	Liver; kidney; muscle; brain.
29 Dehydrogenase, β-hydroxybutyric	DPN	L-β-Hydroxybutyrate→acetoacetate	7	0.05 M	38	Widespread.
30 Dehydrogenase, isocitric	DPN, TPN, Mg ⁺⁺ , Mn ⁺⁺	D-Isocitrate→α-ketoglutarate + CO ₂	7.0	0.0002 M	25	Widespread.
31 Dehydrogenase, lactic	DPN	Lactate→pyruvate	9.3	0.02 M	20	Widespread.
32 Dehydrogenase, malic	DPN or TPN	L(-)Malate→oxalacetate	7.2	0.025 M	37	Brain; kidney; liver; muscle; widespread in plants.
33 Dehydrogenase, succinic	Cytochrome c (?)	Succinate→fumarate	7.4	0.01 M	37	Widespread.
34 Dehydrogenase, triosephosphate	DPN	D-Glyceraldehyde-3-phosphate→1, 3-diphosphoglycerate	8.6-9.0	0.0001 M	27	Widespread.
35 Dehydrogenase, yeast aldehyde	K ⁺ , DPN ⁺ , cysteine	Acetaldehyde→CH ₃ COOH + DPNH + H ⁺				Yeast.
36 Desoxyribonuclease	Mg ⁺⁺ , Mn ⁺⁺	Thymonucleic acid→nucleotides	6-7	0.5%	37	Intestinal mucosa; pancreas; seeds.
37 Emulsin (β-glucosidase)		Salicin→saligenin + β-D-glucose				Small intestine; bacteria; fungi; almonds; plants.
38 Enolase	Mg ⁺⁺ , Mn ⁺⁺ , Zn ⁺⁺	2-Phosphoglycerate→(enol)phosphopyruvate	7	0.1 mg P/ml	20	Muscle; yeasts; leaves.
39 Esterase, acetylcholine		Acetylcholine→acetate + choline	7.4	3 mg/ml	37	Liver; pancreas; brain; blood; insects.
40 Esterase, acetylsalicylic acid		Acetylsalicylic acid→salicylic acid + acetic acid				Brain; kidney; liver.
41 Esterase, cholesterol		Cholesterol esters→cholesterol + acids	5.3 or 7			Liver; kidney; spleen; intestinal mucosa; blood; pancreas; bacteria.
42 Esterase, pectin		Pectin→pectate + methanol	6.2	1%	30	Leaves; fruits; bacteria.
43 Esterase, simple		Ethyl butyrate→ethanol + butyrate	8.0	Saturated	20	Widespread (animals); seeds; fungi.
44 Ficin	H ₂ S, HCN, cysteine	Proteins→amino acids and peptides(?)	5		35	Fig tree sap.
45 Fumarase		Fumaric acid→L(-)malic acid	6.6	0.025 M	40	Liver; muscle; bacteria; fungi; higher plants.
46 β-Galactosidase (lactase)		Lactose→galactose + glucose	5.6	2.5%	38	Bacteria; seeds.
47 α-Glucosidase (maltase)		Maltose→glucose	7.2	50 mg/ml	30	Intestinal mucosa; fungi; malt.
48 β-Glucosidase		β-Glucosides→glucose + aglycon	4.4-5.0	1 mg/ml	30	Intestinal mucosa; liver; kidney; bacteria; fungi; seeds.
49 β-Glucuronidase		β-Glucuronide→glucuronate + alcohol	4.5	0.001 M	38	Widespread (animals); bacteria; higher plants.

50	Glyoxalase	Glutathione	Methylglyoxal→lactate	7	1 mg/ml	25	Liver; kidney; muscle; blood; bacteria; fungi; seeds.
51	Guanase	Mg ⁺⁺ , Mn ⁺⁺	Guanine→xanthine + NH ₃	8.7	Saturated	40	Liver; pancreas; spleen; kidney; seeds.
52	Hexokinase		Hexose + ATP→hexosemonophosphate + ADP	7.5	0.001 M	30	Liver; muscle; kidney; brain; bacteria; yeasts; higher plants.
53	Histaminase		Histamine→aldehyde + H ₂ O ₂ + NH ₃	6.8-7.6	0.01 M	37	Widespread (animals); bacteria; fungi.
54	Histidase	Mg ⁺⁺ , ATP	Histidine→glutamate + formate + NH ₃	8	0.01 M	38	Liver.
55	Hyaluronidase		Hyaluronate→acetylglucosamine + glycuronate	7.0	0.1%	37	Spleen; testes; insects; venoms; bacteria.
56	Invertase (sucrase, saccharase)		Sucrose→glucose + fructose	4.5	4 g/25 ml	20	Intestinal mucosa; invertebrates; fungi; bacteria; higher plants.
57	Lecithinase A	CaCl ₂	Lecithin→lysolecithin + fatty acid	7	Egg yolk	38	Liver; muscle; pancreas; venoms; mushrooms.
58	Lecithinase B		Lysolecithin→glycerylphosphorylcholine + fatty acid	4		41	Liver; spleen; pancreas; brain; fungi; seeds; rice bran.
59	Leucyl peptidase		Leucyl peptides→leucine + other amino acids	8-9	0.05 M	40	Intestinal mucosa; leaves; malt; bacteria; fungi.
60	Lipase	Mg ⁺⁺ , ATP	Fats→glycerol + fatty acids	9	2.5 g/15 ml	30	Pancreas.
61	Lipase		Fats→glycerol + fatty acids	4.7-5.0			Bacteria; fungi; seeds.
62	Lipoxidase		Linoleic acid, etc.→oxidized fatty acids	6.5	0.02%	25	Intestinal mucosa; muscle; seeds.
63	Luciferase	Mg ⁺⁺ , ATP	Luciferin + O ₂ →oxidized luciferin + light	7.2	10 ⁻⁶ M	23	Insects; ostracods; bacteria; fungi.
64	Lysozyme		Bacterial cells→lysed bacterial cells	5.3		38	Nasal mucosa; latex of fig.
65	Oxidase, D-amino acid		D-Amino acids + O ₂ →α-keto acids + H ₂ O ₂ + NH ₃	8.6	0.01 M	38	Widespread (animals); fungi.
66	Oxidase, L-amino acid	HCN, H ₂ S, cysteine	L-Amino acids + O ₂ →α-keto acids + H ₂ O ₂ + NH ₃	8.8	0.015 M	38	Liver; kidney; venoms; fungi; bacteria.
67	Oxidase, ascorbic acid		L-Ascorbic acid + O ₂ →dehydroascorbate + H ₂ O	6.0	0.01 N	26	Widespread (plants).
68	Oxidase, cytochrome c		Ferro-cytochrome c + O ₂ →ferri-cytochrome c + H ₂ O	7.2	0.0001 M	37	Widespread (animals; plants).
69	Oxidase, glucose; (notatin)	Co ⁺⁺ , Mg ⁺⁺ , Mn ⁺⁺	D-Glucose + O ₂ →gluconate + H ₂ O ₂	6.0	1%	39	Fungi.
70	Oxidase, xanthine		Xanthine or aldehyde→uric or other acids	7.5	0.003 M	20	Liver, milk.
71	Papain		Proteins, proteoses, etc.→amino acids	7.5	2%	30	Seeds, latex.
72	Pectinase	Mg ⁺⁺	Pectin→galacturonide	4.0	0.5%	25	Bacteria; fungi.
73	Pepsin		Proteins→proteoses, peptones, amino acids	1.5-2.0	2%	20	Gastric mucosa.
74	Phosphoglucomutase		Glucose-1-phosphate→glucose-6-phosphate	7.5-9.2	10 ⁻⁶ M	30	Widespread (animals; plants).
75	Phosphoglyceromutase	Mg ⁺⁺	3-Phosphoglycerate→2-phosphoglycerate	7	10 ⁻⁵ M	24	Widespread (animals; plants).
76	Phosphomonoesterase I (alkaline phosphatase)		β-Glycerophosphate→H ₃ PO ₄ + glycerol	9.2	0.02 M	37	Widespread (animals); bacteria; fungi.
77	Phosphomonoesterase II (acid phosphatase)		β-Glycerophosphate→H ₃ PO ₄ + glycerol	5-6	0.05 M	37	Prostate; spleen; liver; bacteria; fungi; seeds; tubers.
78	Phosphomonoesterase III	Mg ⁺⁺ , Mn ⁺⁺	Monoesters of phosphate→H ₃ PO ₄ + alcohols	3.4-4.2			Liver; spleen; fungi; seeds.
79	Phosphomonoesterase IV		α-Glycerophosphate→H ₃ PO ₄ + glycerol	5.2-6.2			Blood; bacteria; yeasts.
80	Phosphorylase, amylo-		Dextrin + glucose-1-phosphate→starch or glycogen + phosphate	6.8	0.001 M	30	Widespread (animals, plants).
81	Phytase	Mg ⁺⁺	Phytate→inositol + phosphate	5.5-7.8	0.1%	37	Blood; intest. mucosa; fungi; seeds.
82	Pyrophosphatase I	Mg ⁺⁺ , Mn ⁺⁺	Pyrophosphate→phosphate	7.2-7.8	0.001 M	38	Widespread (animals); fungi; seeds.
83	Pyruvic kinase	ADP, Mg ⁺⁺ , K ⁺	Phospho(enol)pyruvic acid→pyruvic acid + ATP				Yeasts; muscle; E. coli.
84	Q-enzyme	TPN	Amylose→amylopectin	7.0		21	Liver; muscle; seeds; tubers.
85	Reductase, cytochrome c		Ferri-cytochrome c→ferro-cytochrome c	7.3	2x10 ⁻⁵ M	25	Liver; yeasts.
86	Rennin		Casein→paracasein	5.8	Raw milk	40	Calf stomach.
87	Ribonuclease	Mg ⁺⁺ , K ⁺	Ribonucleic acid→ribonucleotides	4-5	0.25 mg P/ml	25	Liver; spleen; pancreas; lungs; bacteria; higher plants.
88	Transaminase		Glutamate + oxalacetate→α-ketoglutarate + aspartate	7.5	0.02 M	40	Widespread (animals, plants).
89	Transphosphorylase, phosphocarbonyl-		1,3-Diphosphoglycerate + ADP→3-phosphoglycerate + ATP	7.9	1 mg/ml	25	Muscle; yeasts.
90	Transphosphorylase, phospho(enol)-	ATP	Phosphopyruvate + AMP→pyruvate + ATP		1.5 mM	38	Muscle; yeasts; higher plants.
91	Trypsin		Proteins, esp. denatured→polypeptides and amino acids	8-9	2.2%	25	Pancreatic juice.
92	Tyrosinase		Catechol, etc. + O ₂ →o-quinone, etc. + H ₂ O	5.5-7	2 mg/ml	25	Melanomas; skin; plants.
93	Urease		Urea→CO ₂ + NH ₃	7.0	1.5%	20	Blood; gastric mucosa; insects; bacteria; fungi; seeds.
94	Xylokinnase		Xylose→xylose-5-PO ₄ + ADP				Liver.

/1/ Abbreviations: ADP=adenosine diphosphate; AMP=adenylic acid, adenosine-monophosphate; ATP=adenosine triphosphate; CoA=coenzyme A; DPN=diphosphopyridine nucleotide, coenzyme I; DPNH=reduced DPN; TPN = triphosphopyridine nucleotide, coenzyme II. /2/ These conditions should be considered as indicative only, since the details vary widely with the method used and the source of the enzyme.

24. AMINO ACIDS: PHYSICAL AND CHEMICAL CHARACTERISTICS

Amino Acids		Empirical Formula	Molecular Weight	Melting Point ¹ °C	Solubility (g/100 ml) ^{2,3}		Specific Rotation				pH at Iso-electric Point ³
Common Name	Synonyms				Water 25°C	Other Solvents	Solvent	g/100ml	Temp °C	[α] _D	
1 L-Alanine	2-Aminopropanoic acid	C ₃ H ₇ O ₂ N	89.1	297	16.51	sl. s. al.; i. eth., acet.	HCl, 1.0N	5.79	15	+14.7	6.11 (DL)
2 β-Alanine	3-Aminopropanoic acid	C ₃ H ₇ O ₂ N	89.1	196	v. s.	v. sl. s. al.; i. eth.					
3 α-Aminobutyric acid	2-Aminobutanoic acid	C ₄ H ₉ O ₂ N	103.12	285	28	0.18 al.; i. eth.	HCl, 20%		20	+14.1	5.98
4 L-Anserine	Methylcarnosine	C ₁₀ H ₁₆ O ₃ N ₄	240.3				H ₂ O	5.0	20	+12.2	
5 L-Arginine	α-Amino-ε-guanidinon-valeric acid	C ₆ H ₁₄ O ₂ N ₄	174.21	238	v. s.	i. al., eth.	HCl, 6.0N	1.65	23	+26.9	10.76
6 L-Asparagine	α-Aminosuccinamic acid	C ₄ H ₈ O ₃ N ₂	132.14	236	2.46	v. sl. s. al.; i. eth.; s. dil. NH ₄ OH	HCl, 3.4N	2.24	20	+34.3	5.41
7 L-Aspartic acid	α-Aminosuccinic acid	C ₄ H ₇ O ₄ N	133.11	269-71	0.50	v. sl. s. al.; i. eth.; s. dil. HCl	HCl, 6.0N	2.0	24	+24.6	2.98
8 L-Canaline	α-Amino-δ-(aminoxyl)butyric acid	C ₄ H ₁₀ O ₃ N ₂	134.14	214			H ₂ O	1.6	21	-8.1	
9 L-Canavanine	α-Amino-6-guanidinooxy-n-butyric acid	C ₅ H ₁₂ O ₃ N ₄	176.2	184			H ₂ O	3.2	20	+7.9	7.93
10 L-Carnosine	β-Alanylhistidine	C ₉ H ₁₄ O ₃ N ₄	226.3				H ₂ O	2.0	20	+20.5	
11 L-Citrulline	α-Amino-δ-carbamidon-valeric acid	C ₆ H ₁₃ O ₃ N ₃	175.2	222	v. sl. s.	i. al.	HCl, 1.0N	2.0	27	+24.3	
12 L-Cystathionine		C ₇ H ₁₄ O ₄ N ₂ S	222.3				HCl, 1.0N	1.0	22	+23.7	
13 Cysteic acid		C ₃ H ₇ O ₅ NS	169.15		s.						
14 L-Cysteine	2-Amino-3-mercapto-propanoic acid	C ₃ H ₇ O ₂ NS	121.15	175-78	v. s.	s. a., alk.	H ₂ O	2.0	21	-10.1	5.07
15 L-Cystine	3,3'-Dithiobis(2-amino-propanoic acid)	C ₆ H ₁₂ O ₄ N ₂ S ₂	240.29	258-61	0.011	i. al., eth.; s. a.	HCl, 1.0N	1.0	24	-214.4	5.02
16 L-Dibromotyrosine	3,5-Dibromotyrosine	C ₉ H ₉ O ₃ NBr ₂	339.0	245 ⁴			HCl, dil.		20	+1.3	
17 L-Dihydroxyphenylalanine	α-Amino-β-3,4-dihydroxyphenylpropionic acid; dopa ⁵	C ₉ H ₁₁ O ₄ N	197.2	280	0.50	i. al., eth.; s. a., alk.	HCl, 4%	1.0	25	-12.0	
18 L-Diiodotyrosine	3,5-Diiodotyrosine; iodogorgoic acid	C ₉ H ₉ O ₃ NI ₂	433.0	194	0.062		HCl, 1.1N	5.1	20	+2.9	4.29 (DL)
19 L-Djenkolic acid	3,3'-Methylenedithiobis(2-aminopropionic acid)	C ₇ H ₁₄ O ₄ N ₂ S ₂	254.3	300-50	0.10		HCl, 1%	2.0	26	-44.5	
20 L-Ergothioneine	Betaine of thiohistidine	C ₉ H ₁₅ O ₂ N ₃ S	228.29				H ₂ O	5.0	21	+116.0	
21 L-Ethionine		C ₆ H ₁₃ O ₂ NS	163.2		s.		HCl, 0.2N	0.8	25	+23.5	
22 L-Glutamic acid	α-Aminoglutaric acid	C ₅ H ₉ O ₄ N	147.13	247	0.86		HCl, 6.0N	1.0	22	+31.2	3.22 (DL)
23 L-Glutamine	α-Aminoglutaramic acid	C ₅ H ₁₀ O ₃ N ₂	146.15	185-6	4.25	v. sl. s. al.; i. eth.					5.65
24 Glycine	Aminoethanoic acid, glycocoll	C ₂ H ₅ O ₂ N	75.0	233	24.99	0.043 al. 90%				0	6.20
25 L-Histidine	α-Amino-β-imidazole-propionic acid	C ₆ H ₉ O ₂ N ₃	155.1	277	4.19	v. sl. s. al.; i. eth.	H ₂ O	1.1	25	-39.0	7.64
26 L-Homocysteine		C ₄ H ₉ O ₂ NS	135.18		s.						
27 L-Homocystine		C ₈ H ₁₆ O ₄ N ₂ S ₂	268.3		v. sl. s.		HCl, 1.0N	1.0	26	+77	
28 L-Hydroxylysine	α, ε-Diamino-6-hydroxy-n-hexanoic acid	C ₆ H ₁₄ O ₃ N ₂	162.2	220			HCl, 1.0N	0.4	22	+7.5	
29 L-Hydroxyproline	4-Hydroxy-2-pyrrolidine-carboxylic acid	C ₅ H ₉ O ₃ N	131.1	238-41	36.11	v. sl. s. al.; i. eth.	H ₂ O	1.0	22	-75.2	5.82
30 L-Isoleucine	2-Amino-3-methylpentanoic acid	C ₆ H ₁₃ O ₂ N	131.17	283-4	4.12	0.09 al.; i. eth. s. hot acet. a.	HCl, 6.1N	5.1	20	+40.6	6.04 (DL)
31 L-Lanthionine	β-Amino-β-carboxyethyl sulfide	C ₆ H ₁₂ O ₄ N ₂ S	208.3								
32 L-Leucine	2-Amino-4-methylpentanoic acid	C ₆ H ₁₃ O ₂ N	131.17	295	2.19	0.022 al.; i. eth.; s. acet. a.	HCl, 6.0N	2.0	26	+15.1	6.04 (DL)
33 L-Lysine	2,6-Diaminohexanoic acid	C ₆ H ₁₄ O ₂ N ₂	146.19	224	v. s.	v. sl. s. al.; i. eth.	HCl, 6.0N	2.0	23	+25.9	9.47
34 L-Methionine	α-Amino-γ-methylthio-n-butyric acid	C ₅ H ₁₁ O ₂ NS	149.21	283	5.75	i. eth.	HCl, 0.2N	0.8	25	+21.2	5.74 (DL)
35 L-Norleucine	α-Aminocaproic acid	C ₆ H ₁₃ O ₂ N	131.17	301	1.149 (DL)	0.017 (DL) al.	HCl, 6.0N	4.3	20	+21.3	6.08 (DL)
36 L-Norvaline	2-Aminopentanoic acid	C ₅ H ₁₁ O ₂ N	117.1	291-2	10.7 ⁶	sl. s. al.; i. eth.	HCl, 20%	5	20	+22.8	
37 Octapine		C ₉ H ₁₈ O ₄ N ₄	246.27								
38 L-Ornithine	2,5-Diaminopentanoic acid	C ₅ H ₁₂ O ₂ N ₂	132.2	225	v. deliq.	v. s. al.; sl. s. eth.	H ₂ O	4.0	27	+16.5 ⁷	
39 L-Phenylalanine	α-Amino-β-phenylpropionic acid	C ₉ H ₉ O ₂ N	165.2	283	2.96	sl. s. al.; i. eth.	H ₂ O	1.9	20	-35.1	5.91 (DL)
40 L-Proline	2-Pyrrolidinecarboxylic acid	C ₅ H ₉ O ₂ N	115.1	220-2	162.3	1.55 al.; i. eth.	HCl, 0.5N	0.6	20	-52.6	6.3
41 Sarcosine	Methyl glycine	C ₃ H ₇ O ₂ N	89.1	210	v. s.	sl. s. al.; i. eth.				0	6.00
42 L-Serine	α-Amino-β-hydroxypropionic acid	C ₃ H ₇ O ₃ N	105.1	228	5.023 (DL)	i. al., eth.	HCl, 1.0N	9.3	25	+14.5	5.68 (DL)
43 L-Thiolhistidine	α-Amino-β-2-thioimidazolepropionic acid	C ₆ H ₉ O ₂ N ₃ S	187.2				HCl, 1.0N	1.0	25	-9.5	
44 L-Threonine	α-Amino-β-hydroxy-n-butyric acid	C ₄ H ₉ O ₃ N	119.12	229-30	20.1 (DL)	i. al., eth.	H ₂ O	1.0	26	-28.4	5.59
45 L-Thyroxine	α-Amino-β-(3,5-diiodo-4-(3',5'-diiodo-4'-hydroxyphenoxy)phenyl)propionic acid	C ₁₅ H ₁₁ O ₄ NI ₄	776.9	235-6	0.001	i. al., eth.	NaOH, 0.133 N in 70% al.			-4.4	
46 L-Tryptophan	α-Amino-β-indolepropionic acid	C ₁₁ H ₁₂ O ₂ N ₂	204.2	289	1.14	sl. s. al.; i. eth.	H ₂ O	1.0	20	-31.5	5.88
47 L-Tyrosine	α-Amino-β-(p-hydroxyphenyl)propionic acid	C ₉ H ₉ O ₃ N	181.2	295	0.045	0.01 al.; i. eth., acet. s. alk.	HCl, 6.3N	4.4	20	-8.6	5.63
48 L-Valine	α-Aminoisovaleric acid	C ₅ H ₁₁ O ₂ N	117.15	293	8.85	0.019 al. (DL)	HCl, 6.0N	3.4	20	+28.8	6.00 (DL)

/1/ Most amino acids decompose when they melt. /2/ a.=acid; acet.=acetone; acet. a.=acetic acid; al.=alcohol; alk.=alkali; deliq.=deliquescent; dil.=dilute; eth.=ether; i.=insoluble; s.=soluble; sl.=slightly; v.=very. /3/ DL=racemic mixture. /4/ Dihydrate. /5/ 3,4-Dihydroxyphenylalanine. /6/ At 50°C. /7/ Dihydrochloride.

25. BIOLOGICAL SUBSTANCES: MOLECULAR SIZE AS DETERMINED BY IONIZING RADIATION

Values are "molecular weights" obtained at room temperature, except where noted, but do not have the accuracy and reliability of certain physical constants. Ionizing radiation can be used to determine approximate shape and structure of molecules as well as molecular weights.

	Material	Reported Molecular Size	Molecular Weight Determined by: ¹		Remarks
			Electrons	Heavy Particles	
1	ACTH	4566		2400	Entire molecule not needed for activity.
2	α -Amylase	100,000-200,000		145,000	Requires 3 simultaneous ionizations for inactivation.
3	Catalase	250,000		58,000 at 90°K 110,000 at 300°K 250,000 at 350°K 500,000 at 385°K	1/4, 1/2, 1, and 2 molecules (?).
4	Chymotrypsin	23,000	50,000	48,000 28,000	Casein digestion assay; polymer (?). Milk clotting assay.
5	Colicine K		60,000-90,000		
6	Cytochrome oxidase	75,000/mole hemin		160,000	Requires 3 simultaneous ionizations for inactivation.
7	Dehydrogenase, succinic	110,000-140,000		310,000	Requires 3 simultaneous ionizations for inactivation.
8	DNA (absorption spectrum unit)	1300 and 5500 found as digestion products.	2100	500 A ²	Breakup of larger DNA units increases absorption coefficient before digestion with DNA-ase.
9	DNA (pneumococcus transforming principle)		700,000(X rays)		Biologically active unit.
10			At least 2 components, one <10 ⁶ , another >2x10 ⁶ .		
11			(5-7)x10 ⁶	Non-spherical	
12	DNA-ase	63,000	62,000	62,000	
13	Dysentery toxin		11,000	11,000	Toxic unit.
14	Gramicidin	8700	6400	6000	
15	Hemocyanin	6.7-8 x 10 ⁶		6,700,000	
16	Hemoglobin, pH5	67,000	46,000	46,000	
17	Hemoglobin, pH7	67,000		66,000	Requires 3 simultaneous ionizations for inactivation; effect on solubility of molecule.
18	Hyaluronidase (HUA-ase)	65,000; 11,000 purified	75,000	75,000 (globular)	
19	Hyaluronic acid (HUA)		100,000	100,000 (long, thin)	Same at 90°K.
20	Hyaluronic acid-hyaluronidase complex			175,000	Assayed for enzyme activity.
21	Insulin	n x 6000	23,000	23,000 (spherical)	Assayed for biological activity.
22	Invertase	120,000	120,000	123,000	Varies with temperature.
23	Mucoprotein, sheep	87,000		82,000	Assumed long and thin.
24	Myosin	840,000	470,000		
25	Oxytocin	1007	1800		Dimer (?).
26	Penicillin	356		550	Cluster size comparable to molecular size.
27	Pepsin	36,000-39,000		39,000	
28	Peptides, di- and tri-	130-250		400-900	Assayed chromatographically; cluster size comparable to molecular size.
29	Ribonuclease	13,000	21,000 30,000 (X rays)		
30	Serum albumin, bovine, bulk	69,000		83,000	Requires 3 simultaneous ionizations for inactivation; effect on solubility of molecule.
31	Serum albumin, bovine, monolayer	69,000		7000	Serological unit.
32	Trypsin	15,000-24,000	34,000	31,000	Dimer (?); independent of substrate used for assay.
33	Trypsin (soybean) inhibitor	24,000 9,000	12,000	12,000	
34	Trypsin - STI complex	41,000 30,000	30,000	30,000	
35	Urease	100,000 ²	87,000	87,000	

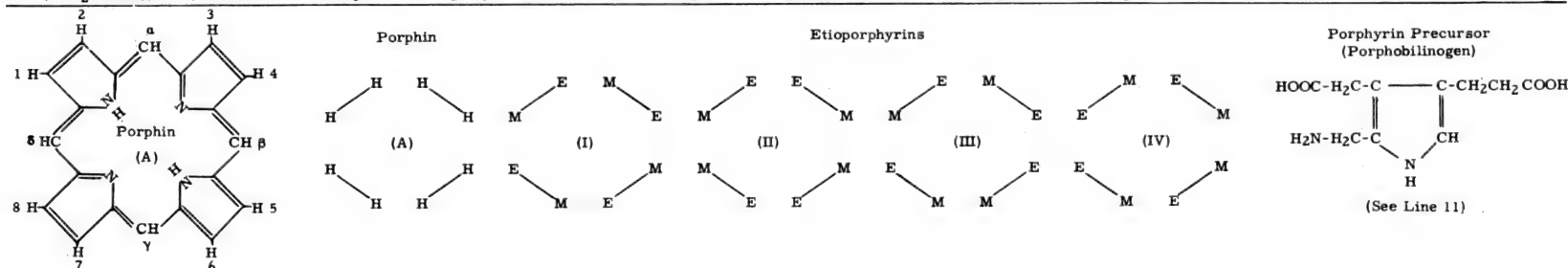
/1/ For general description of method used to obtain molecular sizes from radiation data, and for references to original literature, see Pollard, E. C., et al, Progress in Biophysics 5:72, 1955. /2/ Recent value; old value 480,000.

26. PYRROLE PIGMENTS AND RELATED COMPOUNDS

Part I: PORPHYRINS

These pigments are derived from porphin (A) by substitution of the nuclear hydrogen atoms. There are four stereoisomers called "etioporphyrins" (I, II, III, IV) which are used as the basis for classifying naturally occurring porphyrins. The natural porphyrins correspond to etioporphyrins I and III; chlorophylls and hemoglobins are of type III only; free porphyrins are predominately of type III; small quantities of type I in physiological condition, great quantities in some pathological states.

A = $(-\text{CH}_2\cdot\text{COOH})$; B = $(-\text{CHO})$; D = $(-\text{CO}\cdot\text{CH}_3)$; E = $(-\text{CH}_2\text{CH}_3)$; H = hydrogen; M = $(-\text{CH}_3)$; P = $(-\text{CH}_2\cdot\text{CH}_2\cdot\text{COOH})$; V = $(-\text{CH}:\text{CH}_2)$; X = $(-\text{CO}\cdot\text{CH}_2-)^1$; Y = $[-\text{CH}(\text{OH})\cdot\text{CH}_3]$; Z = $[-\text{CO}\cdot\text{CH}(\text{COO}\cdot\text{CH}_3)-]^1$



	Porphyrin	Substituents in Positions ²								Physical and Chemical Properties ^{3,4}	Spectral Characteristics λ maximum in $\text{m}\mu$ ⁵							Occurrence in Nature
		1	2	3	4	5	6	7	8		Form ⁶	Solvent ⁴	I	II	III	IV	Soret	
1	Chlorocruoroporphyrin	M	B	M	V	M	P	P	M									Fe complex prosthetic group of chlorocruorin of Sabellid worms.
2	Coproporphyrin I (C ₃₆ H ₃₈ O ₈ N ₄)	M	P	M	P	M	P	P	M	MP me. est. = 248-258°C; HCl No. me. est. 1.5; s. eth.-ac. a.	Free, or me. est.	Neutral (eth.-ac. a.)						Free form in feces, urine, erythrocytes, bile, yeast, bacteria. Widespread in traces in animals, plants, microorganisms. Increased pathologically in porphyriurias and porphyrias.
3	Coproporphyrin III (C ₃₆ H ₃₈ O ₈ N ₄)	M	P	M	P	M	P	P	M	MP me. est. = 137°C, remelts at 172°C; HCl No. me. est. = 1.5; s. eth.-ac. a.			623.5	568	528.5	495	405	
4	Deuteroporphyrin IX (C ₃₀ H ₃₀ O ₄ N ₄)	M	H	M	H	M	P	P	M	MP me. est. = 218-224°C; HCl No, me. est. 2.0; s. chl.			621.5	566	526	494		Free form in human feces.
5	Mesoporphyrin (C ₃₄ H ₃₈ O ₄ N ₄)	M	E	M	E	M	P	P	M	MP me. est. = 216°C; HCl No. me. est. 2.5.			Neutral (eth.-ac. a) Pyridine	623.5	567.5	528.5	494.5	391	Free form in human feces, ambergris.
6	Oxopheoporphyrin-a ₅	M	D	M	E	M	Z	P	M									Mg complex of 3, 4, 7, 8-tetrahydroporphyrin, esterified with phytol (in side chain 7): bacteriochlorophyll. Another porphyrin with an acetyl side chain is probably the prosthetic group of milk peroxidase.
7	Pheoporphyrin-a ₅	M	E	M	E	M	Z	P	M									
8	Pheoporphyrin-b ₆	M	E	B	E	M	Z	P	M									
9	Vinylpheoporphyrin-a ₅	M	E	M	V	M	Z	P	M									Mg complex in chlorella mutant esterified with phytol in 7=protochlorophyll. Mg complex of 7, 8-dihydroporphyrin esterified with phytol in 7=chlorophyll a.
10	Vinylpheoporphyrin-b ₆	M	E	B	V	M	Z	P	M									Mg complex of 7, 8-dihydroporphyrin esterified with phytol in 7=chlorophyll b.
11	Phylloerythrin IX (C ₃₃ H ₃₄ O ₃ N ₄)	M	E	M	E	M	X	P	M	MP me. est. = 213°C; HCl No. free porphyrin 7-9.	Free	Acetone	636.8	589.4	560.8	521.8		Free form in feces and bile of ruminants.
12	Porphobilinogen (C ₁₀ H ₁₄ O ₄ N ₂) (monopyrrole)	A	P	-	-	-	-	-	-	MP hydrochloride = 165-170°C; i.c.w., org. solvents.								Obligatory precursor for biosynthesis of porphyrins and heme; in urine in hepatic porphyria, lead and sedormid poisoning; gives red compound with Ehrlich's reagent which is insoluble in CHCl ₃ .
13	Porphyrin a (cytoporphyrin)	Two or three M, 2 P, 1 B, one long alkyl, probably IV.																Fe complex prosthetic group of cytochrome oxidase (cytochrome-a ₃) and cytochromes a, a ₁ .

14	Protoporphyrin IX (C ₃₄ H ₃₄ O ₄ N ₄)	M V M V M P P M	MP me. est. = 225-230°C; HCl No. me. est. 5.5; s. eth.-ac.a.	Free, or me. est.	Neutral (eth.-ac.a) Pyridine	623.5	576	537	502	395	Free form in bone marrow, erythrocytes, feces, chloroma, Harderian glands (rodents), bird egg shells, earthworm. Fe complex (heme) prosthetic group of hemoglobins, myoglobins, catalase, peroxidase (horseradish), cytochrome-b, cytochrome-c (modified). Mg complex in chloroella mutant.
15	Uroporphyrin I (C ₄₀ H ₃₈ O ₁₆ N ₄)	A P A P A P A P	MP me. est. = 293°C; HCl No. 7; i. eth.-ac.a; extr. from aq. sol. (pH 3.0-3.2) with eth. acetate.		Chloroform	626	570.5	536	501	408	Very small amounts in normal human urine, larger amounts in some forms of porphyria and lead poisoning. Also present in mollusk shells and some plants. Normal in urine of Sciurus niger. Porphyrins with 5-7 carboxyl groups also occur.
16	Uroporphyrin III (C ₄₀ H ₃₈ O ₁₆ N ₄)	A P A P A P A P	MP me. est. = 264°C; other properties same as Uroporphyrin I.								Very small amounts in urine, larger amounts in some forms of porphyria and sedormid poisoning. Cu complex: turacin in turaco feathers may serve as source of uroporphyrin III.

/1/ Substituent groups X and Z constitute bridges between C6 and Cy. /2/ Letters in the columns refer to substituents (abbreviated as per code) appearing in the position indicated by column number (numbers correspond to those in reference structural formula). /3/ All porphyrins show a strongly red fluorescence in Wood's light both in acid and alkaline solutions and in many neutral solutions. /4/ Abbreviations: ac.a. = acetic acid; aq. = aqueous; c. = cold; est. = ester; eth. = ether; i. = insoluble; me. = methyl; MP = melting point; s. = soluble. /5/ λ maximum in m μ = wave length of maximum absorption. /6/ Free porphyrin and its ester give the same bands in the same solvent.

Part II: IRON-PORPHYRIN PIGMENTS

Substance	General Nature	Physical and Chemical Properties ¹	Spectral Characteristics λ maximum in mμ ²				Remarks
Heme Compounds							
1 Hematin (hydroxy-hemin) (C ₃₄ H ₃₅ O ₇ N ₄ Fe)	Fe ⁺⁺⁺ complex of protoporphyrin; moderately stable.	s. alk.	Alcohol HCl Acetic acid 10% NaOH Alcoholic NaHCO ₃ Ether Reducing agent (Stoke's) produces hemochromogen bands.	400(131-151) 630-635 580(10.5) 590 650	540 510 400 (Soret)	E _{1%} ¹ _{cm} 1960-2260	Produced by atmospheric oxidation of heme; present in serum in hemolytic and pernicious anemia, malaria, congenital porphyria, certain poisonings, septicemia, severe liver damage; bound to serum albumin as methemalbumin; occasionally present in bile, feces, urine.
2 Heme (protoheme IX) (C ₃₄ H ₃₂ O ₄ N ₄ Fe)	Fe ⁺⁺ complex of protoporphyrin; extremely unstable, easily oxidized to hematin.	Fe removed by dilute HCl in glac. ac. a.	Phosphate buffer, pH 7	550	575 415 (Soret)	E _{1%} ¹ _{cm} 895	Occurs as prosthetic group of hemoglobin; combines with many N-containing bases to form hemochromes.
3 Hemin (chlorohemin) (C ₃₄ H ₃₂ O ₄ N ₄ FeCl)	Crystalline chloride of hematin; stable.	Br. or blk. cryst.; s. dil. alk., strong organic bases; i.a.	0.1N KOH (Best identified by conversion to hemochromogen)	645.2	591 539.7		Not found in nature. Crystals sinter at 240°C, melt at 300°C. Converted to hemochromogen by Na ₂ S ₂ O ₄ + pyridine.
4 Methemalbumin (ferrihemalbumin)	Compound of hematin and serum albumin. Iron is in Fe ⁺⁺⁺ state.	Easily soluble in water as serum albumin.		623 Reduction to Fe ⁺⁺ analogue 570 530 (ferrohemalbumin) (Spectrum unstable in presence of dithionite (cf HbS))	540 500		Found in plasma in blackwater fever, severe anemias, severe liver damage, blood extravasates, etc.
5 Pyridine hemochromogen	Compound of heme + pyridine, 2 molecules of which are coordinately linked with the Fe atom. Term "hemochromogen" or "hemochrome" also used generically for coordination compounds of heme with nitrogenous bases.			558(31-35.3)	525(16.2)		Term "hemochromogen" also used generically for nitrogenous compounds combined with heme; all have similar spectra.
6 Spirographisemin (chlorocruorohemin) (C ₃₃ H ₃₂ O ₅ N ₄ FeCl)	Hemin of chlorocruoroporphyrin.	Same as hemin (above).	CO compound of chlorocruoroheme.	410(Soret)			Prosthetic group in chlorocruorins. No function per se, only as part of chlorocruorins.
Hemoglobin Compounds							
7 Carboxyhemoglobin	Compound of 4 molecules CO per 4 Fe of Hb; iron in Fe ⁺⁺ state.	MW = 66,700. Solubility similar to that of Hb.	568-572(13.7-15)	538-540(14.1-15.3)	418(154)		Diluted solutions are pink (cf HbO ₂); also distinguished from HbO ₂ by stability of spectrum in presence of reducing agents.
8 Hemoglobin (Hb)	Four heme molecules + globin; iron in Fe ⁺⁺ state.	MW = 66,700; easily soluble in water, varying with pH and salt concentration; red-purple color.	Main band at 560 555(12.9-13.6)	430(Soret)	(118-134)	Slight variation according to species of origin.	O ₂ carrier in red corpuscles of all vertebrates. Combines reversibly with O ₂ to form oxyhemoglobin, and with CO to form carboxyhemoglobin (affinity for CO 400x that for O ₂). Several varieties of human Hb known: A, F, S, C, D, E, G.

/1/ Abbreviations: a. = acid; ac.a. = acetic acid; alk. = alkali(ne); blk. = black; br. = brown; cryst. = crystal; dil. = dilute; i. = insoluble; MW = molecular weight; s. = soluble. /2/ λ maximum in m μ = wave length of maximum absorption; figures in parentheses are E_{1%}¹_{cm}, i.e., extinction coefficients of millimolar solutions of 1cm thickness; E_{1%}¹_{cm} = extinction coefficients of 1% solutions of 1cm thickness.

26. PYRROLE PIGMENTS AND RELATED COMPOUNDS (Continued)

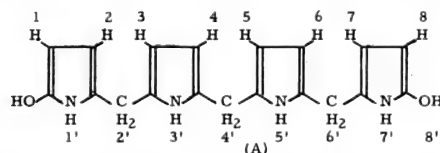
Part II: IRON PORPHYRIN PIGMENTS (Concluded)

Substance	General Nature	Physical and Chemical Properties ¹	Spectral Characteristics maximum in mμ ²	Remarks
9 Methemoglobin (Met Hb)	Like Hb, except iron is in Fe ⁺⁺⁺ state.	MW = 66,700; solubility differs from Hb, depending on pH.	Acid solution 530(3.7-3.8) 500(9.5) 405-407(Soret)(134-154) Alk. solution 577(9.5) 540(9.7) 411 (Soret) (71-90) Addition of Stoke's reagent produces spectrum of Hb (cf hematin)	Small amounts normally present in red blood cells. Larger amounts formed by oxidation (K ferricyanide, nitrites, chlorates, phenacetin, sulfonamides).
10 Myohemoglobin (Mb or MHb)	Heme + globin (different from globin in Hb), Fe ⁺⁺ readily oxidized to Fe ⁺⁺⁺ (Met Hb).	MW = 16,900-19,000. More soluble than Hb in sat. (NH ₄) ₂ SO ₄ ; more alkali resistant than Hb.	Aqueous solution 555 435 Myooyhemoglobin is differentiated from oxyhemoglobin by the position of its α-band at 582 mμ.	In all muscles of higher vertebrates, terrestrial and aquatic; also in nematodes, mollusks. Main function is to store O ₂ in muscles (completely saturated with O ₂ at low pressures).
11 Oxyhemoglobin (HbO ₂)	Compound of Hb with 4 equivalents of oxygen, available physiologically; iron in Fe ⁺⁺ state.	MW = 66,700. Solubility similar to Hb. Bright red color.	577(15.1-16.2) 540-542(14.2-15.3) 412-415 (Soret)(125-128.3)	Present in fresh blood of all vertebrates; diluted solutions are yellow (cf HbCO); reduced to Hb by dithionite with color changes from rose to violet-red.
12 Sulfhemoglobin (HbS)	From treatment of Hb with H ₂ S+ O ₂ (chemical structure not definitely ascertained); not more than 10% HbS formed.	MW = 66,700. Solubility similar to that of Hb.	617 623 (11) Band stable in presence of dithionite (cf methemalbumin) and in presence of NaCN/Na ₂ CO ₃ . 620 (CO) 612 618 (16)	No physiological function; pathological product; occurs in erythrocytes after administration of sulfur, sulfonamides, trinitrotoluene, aromatic amines, and in certain septicemias.
13 Chlorocruorin (Ch)	Globin + chlorocruorheme (molecule contains many such units).	MW about 3 x 10 ⁶ . Solubility similar to Hb.	Reduced form 574 (broad band) Oxidized form 604 560 CO compound 600 507	Found in several species of annelids (Polychaeta), e.g., Spirographis, a marine worm.
14 Choleglobin	Native globin + prosthetic group (composition not clear). Formed by coupled oxidation of Hb with ascorbic acid.	Solubility similar to Hb. Degradation product yields biliverdin.	Fe ⁺⁺ compound (aqueous solution) 629 Fe ⁺⁺⁺ compound (aqueous solution) 674 Fe ⁺⁺ CO compound (aqueous solution) 628	Formed in blood in certain septicemias and poisonings (phenylhydrazine). Is normal Hb degradation product intermediary in bile pigment formation.
15 Erythrocrucorins (invertebrate hemoglobins)	Protoheme + globins (different from vertebrate globins).	Solubility similar to Hb. Combines similarly to Hb with O ₂ and CO ₂ .	Absorption maxima similar to Hb with minor differences according to species.	Occurs in nematodes, annelids, crustaceans, insects, mollusks, echinoderms.
Hematin Enzymes				
16 Catalase	Hematin-containing enzyme; catalyzes decomposition of H ₂ O ₂ , and peroxidation of certain substrates by H ₂ O ₂ .	MW about 220,000. 4 hematin per molecule. Iron is Fe ⁺⁺⁺ , not reducible by Na ₂ S ₂ O ₄ .	629-622(10.8) 544-536 506.5-500 409-400(145) 280-266	Present in aerobic cells, highly concentrated in a few animal tissues (liver, red cells); absent only in strict anaerobes, and a few facultative anaerobes. Catalytic activity inhibited by cyanide, H ₂ S, hydroxylamine, azide, o-aminophenol, 2,4-dichlorophenol and other compounds.
17 Cytochromes a, a ₃ ; a ₁ , a ₂ ³	Heme of porphyrin a (Part I, No. 13) is prosthetic group of a, a ₃ and probably a ₁ ; heme of chlorin is prosthetic group of a ₂ .	MW unknown. a ₃ and a bound in mitochondria, probably as lipoprotein complex. Soluble only as complex with cholate and similar compounds.	Reduced a ₃ + a 605-600 (due to a ₃ and a) 445 (due mainly to a ₃) a ₃ CO 590-430 (a does not react with CO) Reduced a ₁ 590 435-440 Reduced a ₂ 635-630 (Soret band weak or absent)	Cytochromes a ₃ , probably also a ₁ and a ₂ , react directly with oxygen (oxidases; cytochrome-a only electron carrier); a ₃ + a widespread in animals, plants, and some bacteria; a ₁ and a ₂ in other bacteria. ⁴
18 Cytochrome-c, c ₁ ³	Prosthetic group based on hematoporphyrin modified by firm sulfur linkages to cysteine groups of protein.	MW = 13,500-16,000. Soluble, very stable protein; non-auto oxidizable, does not react with CO. E ₀ ' (pH 7.0, 37°C) = 0.25 volts.	Cytochrome Fe ⁺⁺ 550(26-28) 522(15.5-16.9) 415(143) 345 316 Fe ⁺⁺⁺ 565 (indistinct) 530(9.4-9.7) 407(112) 346	Occurs in all animal and plant cells, and in cells of most microorganisms. Specific electron carrier reacting with cytochrome-a.
19 Cytochromes b	Prosthetic group protoheme; for b ₂ = protoheme + flavin.	Only b ₂ (lactic dehydrogenase of yeast) prepared as soluble cryst. enzyme; b in mitochondria. All members rendered autooxidizable, do not react with CO. E ₀ ' of b (pH 7.0, 37°C) = 0 (approx.)	Reduced band in region 565-555 Soret band about 430	Essential electron carriers below cytochrome-c in the respiratory chain. Occur in all living cells of animals, plants and microorganisms, except strict anaerobes.

20	Peroxidases	Prosthetic groups (1) for horseradish and cytochrome-c peroxidases = protohemin; (2) for lactic peroxidase = hemin (of a different porphyrin); (3) for myeloperoxidase = group similar to that of choleglobin.	MW = 44,100, with one hema-tin group. Soluble enzyme. Iron Fe^{+++} reduced by dithionite.	In neutral solution 645(12) 583 548 498 558 594 (weak) Dithionite	Peroxidases occur in plants and animals; biological functions still inadequately known. Detection by treatment of material with H_2O_2 + benzidine: green color develops.
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/1/ Abbreviations: a. = acid; ac. a. = acetic acid; alk. = alkali(ne); blk. = black; br. = brown; cryst. = crystal; dil. = dilute; i. = insoluble; MW = molecular weight; s. = soluble. /2/ λ maximum in $m\mu$ = wave length of maximum absorption; figures in parentheses are $E_{1cm}^{1\%}$ i.e., extinction coefficients of millimolar solutions of 1 cm thickness; $E_{1cm}^{1\%}$ = extinction coefficients of 1% solutions of 1 cm thickness. /3/ As usually used, "cytochrome oxidase" (cytochrome-c oxidase) equals $a_3 + a$, strictly only a_3 (atmungsferment); cytochromes a_1 and a_2 are also oxidases in microorganisms. /4/ Respiration inhibited by cyanide, azide, particularly CO (specific light reversion of inhibition).

Part III: THE BILIRUBINOIDS AND RELATED DIPYRRYL COMPOUNDS



These are derivatives of the tetrapyrrolic structure (A) formed by varying degrees of oxidation, and substitution of the nuclear H atoms 1, 2, 3, 4, 5, 6, 7, 8. While formula (A) describes the bilirubinoids as linear tetrapyrrolic chains with terminal hydroxyl groups, their structure is more correctly described as that of a tetrapyrrolic ring closed by a hydrogen bond between oxygen atoms ($N \cdots CO \cdots HOC \cdots N$). All natural members are derived from Fischer's protoporphyrin IX by fission at the α -methene link. They are therefore known as Bilirubinoids IX-a. The main characteristics are as follows:
 (Gm) Gmelin reaction: given by bilirubins; the later stages also by biliverdins and bilipurpurins.
 (Di) Diazo reaction: depending on the splitting of the molecule at a central $-CH_2-$ group.
 (Eh) Ehrlich reaction: characteristic of bilanes.
 (Pe) Pentdyopent reaction: given by most bile pigments, hematin compounds and dipyrrolic methenes.
 (Sc) Schlesinger reaction: given by dipyrrolic methenes.
 (Fe) Ferric chloride reaction: given by all except trienes and more highly oxidized pigments, and except tetrahydromesobilane and -bilene.

Substituent groups: E = $(-CH_2CH_3)$; H, H_2 = hydrogen; M = $(-CH_3)$; OH = hydroxyl; P = $(-CH_2CH_2COOH)$; V = $(-CH:CH_2)$. + = positive reaction; (+) = non-characteristic reaction; - = negative reaction.

Substance	Substituents in Positions								Physical and Chemical Properties ¹	Spectral Characteristics λ maximum in $m\mu$ ²	Reactions						Remarks
	1	2	3	4	5	6	7	8			Gm	Di	Eh	Pe	Sc	Fe	
	1'	2'	3'	4'	5'	6'	7'	8'									
Bilanes and Hydrobilanes																	
1 Mesobilane (mesobilirubinogen, urobilinogen IX-a) (C ₃₃ H ₄₄ O ₆ N ₄)	M	E	M	P	P	M	M	E	Colorl. cryst.; MP = 199°C; s. al., am. al., chl., dil. alk.; sl. s. eth.; i.w.	Red pigment (s. chl.) on treatment with Ehrlich reagent: about 560 $m\mu$ (64.5).	-	-	+	+	-	+	Hemoglobin degradation product. In feces; a little in normal, more in pathological urine and bile. Distinguish from 2 (below) by Fe reaction or by violet pigment (bands at 665, 600, 510 $m\mu$) on warming with NaOH-CuSO ₄ .
2 Tetrahydromesobilane (stercobilinogen) (C ₃₃ H ₄₂ O ₆ N ₄)	M	E	M	P	P	M	M	E	Colorl., non-cryst.; MP = 125-150°C; s. al., am. al., chl., dil. alk.; sl. s. eth.; i.w.		-	-	+	-	-	-	Main excretory product of hemoglobin in most vertebrates. Distinguish from 1 (above) by negative Fe reaction, or NaOH-CuSO ₄ reaction (only one band at 530-500 $m\mu$).
Bilenes and Hydrobilenes																	
3 Mesobilene (urobilin IX-a) (C ₃₃ H ₄₂ O ₆ N ₄)	M	E	M	P	P	M	M	E	Reddish yel. col.; MP free substance = 190°C, \cdot HCl = 199°C; s. al., am. al., chl., dil. alk.; sl. s. eth.; i.w.	Dioxane 452(25.1) 330(3.6) Alcohol HCl 490(50.1) 375(7.4) Zn complex in me. al. 509.5	-	-	-	+	+	+	Oxidation product of 1 (above). Distinguish from 4 (below) by positive Fe and Pe reactions, optical inactivity and band position in alcohol HCl in reversion spectroscopy.
4 Tetrahydromesobilene (stercobilin) (C ₃₃ H ₄₀ O ₆ N ₄)	M	E	M	P	P	M	M	E	Reddish yel. col.; MP free substance = 236°C, \cdot HCl = 165°C; s. al., am. al., chl., dil. alk.; sl. s. eth.; i.w.	Dioxane 456(33.0) 372(8.5) Alcohol HCl 488(55) E band (Na salt in H ₂ SO ₄) 530 Zn complex in alcohol 506.5 Cu complex in alcohol 515 [a] _D ²⁰ free 320 [a] _D ²⁰ \cdot HCl 3800	-	-	-	-	+	-	Oxidation product of 2 (above). Distinguish from 3 (above) by stability in presence of FeCl ₃ , negative Pe reaction and optical activity (levorotatory).

/1/ Abbreviations: ac. a. = acetic acid; acet. = acetone; al. = alcohol; alk. = alkali(ne); am. = amyl; bz. = benzene; chl. = chloroform; col. = color; colorl. = colorless; cryst. = crystal(line); dil. = dilute; dimeth. = dimethyl; est. = ester; eth. = ether; eth. ac. = ethyl acetate; glac. = glacial; grn. = green; i. = insoluble; MP = melting point; me. = methyl; or. = orange; purp. = purple; pyr. = pyridine; sl. = slightly; s. = soluble; vlt. = violet; w. = water; yel. = yellow. /2/ λ maximum in $m\mu$ = wave length of maximum absorption; figures in parentheses are $E_{1cm}^{1\%}$ i.e., extinction coefficients of millimolar solution of 1 cm thickness.

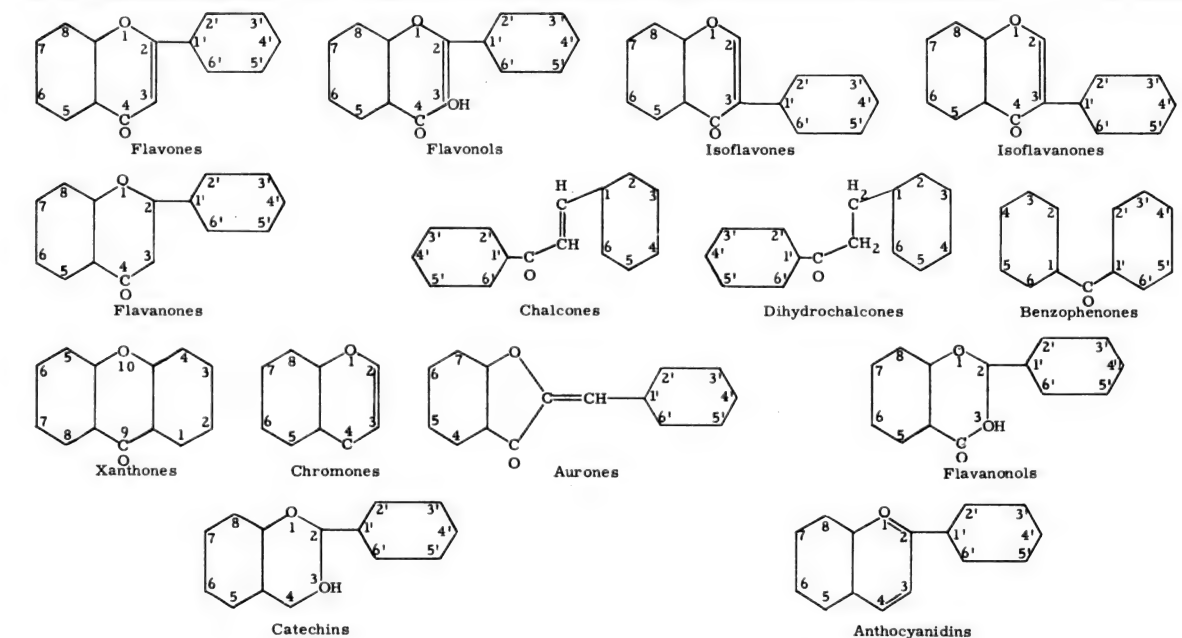
26. PYRROLE PIGMENTS AND RELATED COMPOUNDS (Concluded)
Part III: THE BILIRUBINOIDS AND RELATED DIPYRRYL COMPOUNDS (Concluded)

Substance	Substituents in Positions								Physical and Chemical Properties ¹	Spectral Characteristics λ_{maximum} in $\text{m}\mu^2$			Reactions					Remarks	
	1	2	3	4	5	6	7	8					Gm	Di	Eh	Pe	Sc		Fe
Biladienes																			
5 Bilirubin ($\text{C}_{33}\text{H}_{36}\text{O}_6\text{N}_4$)	M	V	M	P	M	M	V	OH	Or. col.; MP dimeth. ester 198-200°C; sol. hot pyr., hot chl., CCl_4 , dil. alk.; sl.s. acet., eth. ac.; i.w., al., eth.	Chloroform NaOH	450(56) 420		+	+	+	+	+	Breakdown product of heme compounds in bile, feces of newborn, hemorrhagic infarcts (hematoidin), gallstones. Present in serum, urine, tissues during jaundice. Reduction with Na/Hg gives mesobilane. Sc reaction with iodine: 635 $\text{m}\mu$ band of bilipurpurin.	
6 Mesobilerythrin (mesobilirhodin) ($\text{C}_{33}\text{H}_{40}\text{O}_6\text{N}_4$)	M	E	M	P	M	M	E	O	Red col.; s. bz., chl.; sl.s. eth.; i.w.	HCl/chloroform HCl, 5% Zn complex in alcohol	605(weak) 560 630(weak)	557(weak) 495 509	497	-	-	+	+	+	Prosthetic group of phycoerythrin of red and some blue algae; efficient photosensitizer in algal photosynthesis. Related compound in Aplysia.
7 Mesobilirubin ($\text{C}_{33}\text{H}_{40}\text{O}_6\text{N}_4$)	M	E	M	P	M	M	E	OH	Yel. or or. col.; MP free substance = 315°C, dimeth. ester = 190°C; s. pyr., chl., dil. alk.; sl. s. eth. ac., eth.; i.w.	Chloroform	425(61.4)			+	+	+	+	Possibly present in small intestine. Reduction with Na/Hg gives mesobilane. Sc reaction with iodine: 625 $\text{m}\mu$ band of mesobilipurpurin.	
8 Mesobiliviolin ($\text{C}_{33}\text{H}_{40}\text{O}_6\text{N}_4$)	M	E	M	P	M	M	E	OH	Vlt. col.; MP $\cdot \text{HCl}$ = 165°C, s. bz., chl.; sl.s. eth.; i.w.	Chloroform Aqueous HCl Zn complex in alcohol	570-575 598 625-629	575(weak)		-	-	+	+	+	In human feces, probably derived from mesobilane. Prosthetic group of phycocyanins (chromoproteins of red and blue algae) which act as efficient photosensitizers in algal photosynthesis. Related compound in Aplysia.
Bilatrienes																			
9 Biliverdin ³ ($\text{C}_{33}\text{H}_{34}\text{O}_6\text{N}_4$)	M	V	M	P	M	M	V	OH	Blue-grn. col.; MP dimeth. est. = 215°C; s. hot meth. al., hot glac. ac. a., dil. alk.; sl.s. eth., chl., dil. HCl; i.w.	Methyl alcohol 5% HCl/methyl alcohol Aqueous HCl/alcohol λ_{max} 675 λ_{min} 500	640(10.4) 680(28) λ_{max} 675 λ_{min} 500	392(25) 377(48)		+	-	+	-	-	In gr. bile of some animals, egg shells of many birds (oocyan), placenta of some mammals (uteroverdin), hematomas. Green stage of Gmelin reaction. Biliverdin-iron present as prosthetic group of (inactive) liver catalase. Sc reaction with iodine same as for bilirubin.
10 Glucobilin (mesobiliverdin) ($\text{C}_{33}\text{H}_{38}\text{O}_6\text{N}_4$)	M	E	M	P	M	M	E	OH	Grn.-blue col.; MP free substance = 316-318°C, dimeth. est. = 214-232°C; s. hot me. al., dil. alk.; sl.s. eth., chl., dil. HCl; i.w.	5% HCl/methyl alcohol	670(30.9)	363(46.8)	309(17.8)	+	-	+	-	-	Glucobilin or related bilatrienes present in hemolymph and integuments of insects (coelenterates, mollusks, annelids). Sc reaction with iodine same as for mesobilirubin.
Biladienones																			
11 Bilichrysin ($\text{C}_{33}\text{H}_{34}\text{O}_7\text{N}_4$) and meso compound	M	V	M	P	M	M	V	O	Yel. col. MP; (mesobilichrysin) = 240°C.	Mesobilichrysin in NH_3 /alcohol	416(40.5)	311(23)		(+)	(+)	+	(+)	+	Isomerization product of bilipurpurin.
12 Bilipurpurin ($\text{C}_{33}\text{H}_{34}\text{O}_7\text{N}_4$) and related compounds	M	V	M	P	M	M	V	OH	Red-purp. col.	Zn complex in alcohol Meso compound	635-645 619-630			-	-	+	+	-	Purple stage of Gmelin reaction and other oxidations of bilirubins and biliverdin. Resembles biliviolins.
Bilenediones																			
13 Choletelin ($\text{C}_{33}\text{H}_{34}\text{O}_8\text{N}_4$) and related compounds	M	V	M	P	M	M	V	OH	Yel. col.	HCl/alcohol Zn complex in alcohol	490-495 505-515			-	-	+	+	-	Yellow stage of Gmelin reaction and other oxidations of bilirubin, biliverdin, bilipurpurin. Resembles urobilins.
Dipyrryl Compounds																			
14 Probilifuscins, bilifuscins, propentdyopents ($\text{C}_{16}\text{H}_{18-20}\text{O}_{4-5}\text{N}_2$) their oxidation products.	Not definitely established; probably dihydroxydipyrryl methanes and their oxidation products.								Colorl. except bilifuscins, which are brown polymerization and oxidation products of probilifuscins. Propentdyopents are red in NaOH - $\text{Na}_2\text{S}_2\text{O}_4$ (pentdyopent).	Characteristic absorption bands in NaOH - $\text{Na}_2\text{S}_2\text{O}_4$ at about 525 (523-525) account for name "pent-dyopent."			No characteristic reaction.			Secondary products of oxidation of bile pigments and hematin compounds, excreted in urine and feces in jaundice and liver disease; present in gallstones.			

/1/ Abbreviations: ac. a. = acetic acid; acet. = acetone; al. = alcohol; alk. = alkali(ne); am. = amyl; bz. = benzene; chl. = chloroform; col. = color; colorl. = colorless; cryst. = crystal(line); dil. = dilute; dimeth. = dimethyl; est. = ester; eth. = ether; eth. ac. = ethyl acetate; glac. = glacial; grn. = green; i. = insoluble; MP = melting point; me. = methyl; or. = orange; purp. = purple; pyr. = pyridine; sl. = slightly; s. = soluble; vlt. = violet; w. = water; yel. = yellow. /2/ λ_{maximum} in $\text{m}\mu$ = wave length of maximum absorption; figures in parentheses are $\text{E}_{1\text{cm}}^{1\text{mM}}$, i.e., extinction coefficients of millimolar solutions of 1 cm thickness. /3/ Oxidation product of bilirubin.

27. PLANT PIGMENTS: OCCURRENCE, PHYSICAL AND CHEMICAL CHARACTERISTICS

Part I: FLAVONES, CHALCONES, XANTHONES, AND RELATED COMPOUNDS



Pigment	Melting Point, °C ¹	Hydroxyl Position, C-	Methoxyl Position, C-	Source
Flavones				
1 Acacetin	261 (203)	5, 7	4'	Robinia pseudoacacia (leaves).
2 Acrammerin	350 (232)	5, 7, 3', 4', 5'	8	Gleditsia triacanthos (pods).
3 Apigenin	348 (182)	5, 7, 4'		Parsley (leaves, stems, flowers), Dahlia spp (white flowers).
4 Baicalein	266 (192)	5, 6, 7		Scutellaria baicalensis (roots).
5 Chrysin	275 (192)	5, 7		Populus monilifera balsamifera (buds), Oroxylium indicum (bark).
6 Chrysoeriol	325 (215)	5, 7, 4'	3'	Eriodictyon glutinosum.
7 Diosmetin	255 (196)	5, 7, 3'	4'	Scrophularia nodosa, Dahlia variabilis.
8 Flavone	100			Primula spp.
9 Fukugetin	5, 7, 3', 4'	5, 7, 3', 4'	(6-epoxy-p-hydroxy-cinnamoyl)	Garcinia spicata (bark), Xanthocymus ovalifolia (bark).
10 Genkwanin	286 (198)	5, 4'	7	Daphne genkwa (flowers), Prunus puddum (bark).
11 5-Hydroxy-7, 4'-methoxyflavone	175 (199)	5	7, 4'	Betula spp (leaf buds).
12 Lotoflavin	300 (178)	5, 7, 2', 4'		Lotus arabeus.
13 Luteolin	331 (226)	5, 7, 3', 4'		Chrysanthemum indicum (flowers), Digitalis purpurea (leaves), celery (seeds).
14 Nobiletin	134		5, 6, 7, 8, 3', 4'	Citrus nobilis (fruit peel).
15 Oroxylin-A	232 (132)	5, 7	6	Oroxylium indicum (root bark).
16 Pectolarigenin	216 (151)	5, 7	6, 4'	Linaria vulgaris (flowers).
17 Primetin	231 (189)	5, 8		Primula modesta (leaves).
18 Primuletin	157 (145)	5		Primula spp.
19 Scutellarein	350 (237)	5, 6, 7, 4'		Scutellaria altissima (flowers, leaves), Galeopsis tetrahit, Teucrium chamaedrys.
20 Tectochrysin	163 (149)	5	7	Populus pyramidalis, P. nigra (buds), Pinus strobus (heartwood).
21 Tricin	292 (254)	5, 7, 4'	3', 5'	Triticum dicoccum (leaves).
22 Wogonin	203 (153)	5, 7	8	Scutellaria baicalensis.
Flavonols				
23 Aurantetin	140		3, 6, 7, 8, 4'	Citrus aurantium (fruit peel).
24 Ayanin	173 (177)	5, 3'	3, 7, 4'	Distemonanthus benthamianus (heartwood).
25 Datisctetin	276 (141)	3, 5, 7, 2'		Datisca cannabina (leaves), Paeonia albiflora var. hortensis.
26 Erianthin	154 (163)	5, 7	3, 6, 8, 3', 4'	Blumea eriantha (flowers).
27 Fisetin	330 (200)	3, 7, 3', 4'		Rhus spp, Quebracho colorado (wood).
28 Galangin	215 (144)	3, 5, 7		Alpinia officinarum (rhizome).
29 Galangin monomethyl ether	299 (176)	5, 7	3	A. officinarum (rhizome).
30 Gardenin	162 (136)	5	3, 6, 8, 3', 4', 5'	Gardenia lucida (gum).
31 Gossypetin	314 (230)	3, 5, 7, 8, 3', 4'		Gossypium spp, Hibiscus spp (flowers).
32 Herbacetin	283 (193)	3, 5, 7, 8, 4'		Gossypium indicum, G. herbaceum (flowers).
33 Hibiscetin	350 (244)	3, 5, 7, 8, 3', 4', 5'		Hibiscus sabdariffa (flowers).
34 Icaritin	240 (147) ²	3, 5, 7	4'- (8-γ-hydroxy-isoamyl)	Epimedium macranthum.
35 Isorhamnetin	305 (205)	3, 5, 7, 4'	3'	Cheiranthus cheiri, Trifolium pratense, Cassia acutifolia, etc.
36 Izalpinin	195 (171)	3, 5	7	Alpinia spp (seeds).
37 Kanugin	205		3, 7, 3'- (4', 5'-methylenedioxy)	Pongamia glabra.

/1/ Values in parentheses are for the fully acetylated derivatives unless otherwise noted. /2/ Tetraacetate.

27. PLANT PIGMENTS: OCCURRENCE, PHYSICAL AND CHEMICAL CHARACTERISTICS (Continued)

Part I: FLAVONES, CHALCONES, XANTHONES, AND RELATED COMPOUNDS (Continued)

Pigment	Melting Point, °C ¹	Hydroxyl Position, C-	Methoxyl Position, C-	Source
Flavonols (concluded)				
38 Karanjin	159		3 [(7,8:5'',4'') - furano]	Pongamia glabra.
39 Kaempferide	229 (195)	3, 5, 7	4'	Alpinia officinarum (rhizomes)
40 Kaempferol	278 (181)	3, 5, 7, 4'		Robinia pseudoacacia (flowers), Indigofera arrecta (leaves), Gossypium herbaceum, etc.
41 Melisimplexin	185		3, 5, 6, 7 (3', 4'-methylenedioxy)	Melicope simplex (bark).
42 Melisimplin	235 (202)	5	3, 6, 7 (3', 4'-methylenedioxy)	Melicope simplex (bark).
43 Meliternatin	199		3, 5 (6, 7, 3', 4'-dimethylenedioxy)	Melicope ternata (bark).
44 Meliternin	186		3, 5, 7, 8 (3', 4'-methylenedioxy)	Melicope ternata (bark).
45 Morin	290 (145) ³		3, 5, 7, 2', 4'	Chlorophora tinctoria (wood).
46 Myricetin	361 (216)	3, 5, 7, 3', 4', 5'		Myrica magi, M. rubra (bark), Ampelopsis meliaeifolia.
47 Nor-β-anhydrocaritin ⁴	305 (212)	3, 5, 4'	(2'', 2''-dimethyl-[7, 8:6'', 5''] - chromano)	Phellodendron amurense (leaves).
48 Ombuin	230 (212)	3, 5, 3'	7, 4'	Phytolacca dioica (leaves).
49 Patuletin	264 (172)	3, 5, 7, 3', 4'	6	Tagetes patula (flowers).
50 Quercetagenin	320 (211)	3, 5, 6, 7, 3', 4'		Tagetes patula, T. erecta (flowers).
51 Quercetin	317 (194)	3, 5, 7, 3', 4'		Quercus tinctoria (bark), Prunus serotina, Helianthus annuus, etc.
52 Rhamnazin	216 (155)	3, 5, 4'	7, 3'	Polygonum hydropiper, Rhamnus infectoria.
53 Rhamnetin	296 (192)	3, 5, 3', 4'	7	Rhamnus cathartica.
54 Rhamnocitrin	222 (201)	3, 5, 4'	7	Rhamnus cathartica (fruit).
55 Robinetin	330 (224)	3, 7, 3', 4', 5'		Robinia pseudoacacia, Gleditsia monosperma (wood).
56 Tambuletin	271 (142)	3, 5, 7, 4'	8	Zanthoxylum acanthopodium (seeds).
57 Tambulin	205 (165)	3, 5	7, 8, 4'	Z. acanthopodium (seeds).
58 Tangeretin	154		3, 5, 6, 7, 4'	Citrus nobilis deliciosa (fruit peel).
59 Ternatin	211 (166)	5, 4'	3, 7, 8, 3'	Melicope ternata (bark).
60 Thapsin (Calycopteris)	226 (129)	5, 4'	3, 6, 7, 8	Digitalis thapsi, Calycopteris floribunda (leaves).
61 Biochanin-A (Olmelin)	212 (190)	5, 7	4'	Cicer arietinum (seeds), Gleditsia triacanthos.
62 Daidzein	323 (187)	7, 4'		Soja hispida (seeds).
63 Ferreirin	212	5, 7, 2'	4'	Ferreirea spectabilis (heartwood)
64 Formononetin	257 (170)	7	4'	Ononis spinosa.
65 Genistein	291 (202)	5, 7, 4'		Genista tinctoria (shoots), Soja hispida (seeds).
66 Homoferreirin	168 (137)	5, 7	2', 4'	Ferreirea spectabilis (heartwood).
67 Iriogenin	185 (128)	5, 7, 3'	6, 4', 5'	Iris florentina (rhizome)
68 Muningin	285 (233)	6, 4'	5, 7	Pterocarpus angolensis (heartwood).
69 Orobol	271 (212)	5, 7, 3', 4'		Orobolus tuberosus.
70 Osajin	193 (152), 162 ⁵	5, 4'	(6-isopentenyl-2'', 2''-dimethyl-[7, 8:6'', 5''] - pyrano)	Maclura pomifera.
71 Pomiferin	201 (154)	5, 3', 4'	(6-isopentenyl-2'', 2''-dimethyl-[7, 8:6'', 5''] - pyrano)	M. pomifera.
72 Prunetin	242 (225)	5, 4'	7	Prunus spp (bark), Pterocarpus angolensis.
73 Pseudobaptigenin	299 (173)	7	(3', 4'-methylenedioxy)	Baptisia spp (root).
74 Santal	223 (170)	5, 3', 4'	7	Santalum album (wood), Baphia nitida.
75 Tectorigenin	227 (190)	5, 7, 4'	6	Iris tectorum, Belamcanda chinensis (rhizomes).
Flavanones				
76 Alpinetin	225	7	5	Alpinia chinensis.
77 Butin	215 (131)	7, 3', 4'		Butea frondosa (flowers).
78 Citronetin	225 (119)	5, 7	2'	Citrus limonum (fruit peel).
79 Cryptostrobin	203	5, 7	(6-methyl)	Pinus strobus (heartwood).
80 Desmethoxymatteucinol	203 (162) ⁶	5, 7	(6, 8-dimethyl)	Matteucia orientalis.
81 Eriodictyol	267 (137)	5, 7, 3', 4'		Eriodictyon spp (leaves).
82 Hesperetin	228 (82)	5, 7, 3'	4'	Citrus spp (fruit peel)
83 Homoeriodictyol	225 (163)	5, 7, 4'	3'	Eriodictyon glutinosum (leaves).
84 Isosakuranetin	194 (140)	5, 7	4'	Citrus trifoliata (flowers).
85 Liquiritigenin	207 (186)	7, 4'		Glycyrrhiza glabra var glandulifera.
86 Matteucinol	174 (170)	5, 7	4' (6, 8-dimethyl)	Matteucia orientalis
87 8-Methoxybutin	197 (124)	7, 3', 4'	8	Coreopsis grandiflora (flowers)
88 Naringenin	251 (127)	5, 7, 4'		Citrus decumana (fruit peel), Salix purpurea (bark), Prunus serotina (heartwood).
89 Pinocembrin	195	5, 7		Pinus cembra, P. montana, P. banksiana (heartwood).
90 Pinostrobin	102	5		Pinus strobus (heartwood)
91 Plathymenin	229 (151)	6, 7, 3', 4'		Plathymentia reticulata (wood).
92 Ponkanetin	152		5, 6, 7, 8, 4'	Citrus poonensis (unripe fruit peel).
93 Sakuranetin	154 (97)	5, 4'	7	Prunus spp (bark).
94 Strobopinin	227	5, 7	(8-methyl)	Pinus strobus (heartwood).
Chalcones (C), Dihydrochalcones (D), Benzophenones (B)				
95 Butein (C)	215 (131)	3, 4, 2', 4'		Coreopsis douglasii, Dahlia variabilis (flowers).
96 Isocarhamin (C)	228	4, 2', 3', 4', 6'	(3'-glucoside) ⁷	Carthamus tinctorius (flowers).
97 Isosalipurposide (C)	173	4, 2', 4', 6'	(2'-glucoside) ⁸	Salix purpurea (old bark).
98 Lanceoletin (C)	(166)	3, 4, 2', 4'	3'	Coreopsis lanceolata, C. saxicola (ray flowers).
99 Lonchocarpin (C)	108	2'	(2'', 2''-dimethyl-[5'', 6'': 3', 4'] - pyrano)	Lonchocarpus sericeus (seeds and roots).
100 Pedicellin (C)	98		2', 3', 4', 5', 6'	Didymocarpus pedicellata (leaves).
101 Pedicin (C)	145 (183) ⁹	2', 5'	3', 4', 6'	D. pedicellata (leaves).

/1/ Values in parentheses are for the fully acetylated derivatives unless otherwise noted. /3/ 3,7,2',4'-Tetraacetate. /4/ Aglucone of amurensin.
 /5/ Acetate exists in two forms. /6/ Mono-(probably 7-)-acetate. /7/ Forms isocarhamidin (5,6,7,4'-tetrahydroxyflavanone) when hydrolyzed.
 /8/ Forms naringenin (5,7,4'-trihydroxyflavanone) when hydrolyzed. /9/ Dbenzoate.

27. PLANT PIGMENTS: OCCURRENCE, PHYSICAL AND CHEMICAL CHARACTERISTICS (Continued)

Part I: FLAVONES, CHALCONES, XANTHONES, AND RELATED COMPOUNDS (Concluded)

Pigment	Melting Point, °C ¹	Hydroxyl Position, C-	Methoxyl Position, C-	Source
Chalcones (C), Dihydrochalcones (D), Benzophenones (B) (concluded)				
102 Stilopsidin (C)	232 (156)	3, 4, 2', 4', 5'		Plathymenia reticulata (wood), Coreopsis stillmanii (flowers).
103 Strobilochrysin (C)		2', 4', 6'	(5-methyl)	Pinus strobus (heartwood).
104 Aseboigenin (D)	168 (77)	4, 2', 6'	4'	Andromeda japonica (leaves).
105 Phloretin (D)	264 (165)	4, 2', 4', 6'		Micromelum teprocarpum, root bark of fruit trees
106 Cotoin (B)	131 (94)	2, 6	4	Coto spp (bark).
107 Hydrocotoin (B)	98	2	4, 6	Coto spp (bark).
108 p-Hydroxybenzophenone	134 (81)	4		Talauma mexicana (leaves).
109 Maclurin (B)	222	2, 4, 6, 3', 4'		Morus tinctoria (wood)
110 Methylhydrocotoin (B)	115		2, 4, 6	Paracoto spp (bark).
111 Methylprotocotoin (Hydroxyleucotin) (B)	135		2, 4, 6(3', 4'-methylenedioxy)	Coto spp (bark).
112 Protocotoin (B)	142	2	4, 6 (3', 4'-methylenedioxy)	Coto spp (bark).
Xanthones (X), Chromones (C), Aurones (A)				
113 Decussatin (X)	150 (167)	8	3, 4, 7	Swertia decussata (flowers).
114 Desmethylerwertianol (X)	317	1, 3, 5, 8		Swertia tosaensis (roots).
115 Euxanthone (X)	240 (185)	1, 7		Platonia insignis (heartwood).
116 Gentisin (X)	267 (197)	1, 7	3	Gentiana lutea, Swertia japonica (roots).
117 Jacareubin (X)	257 (213)	1, 5, 6	(2', 2'-dimethyl- [5', 6':2, 3] -pyrano)	Calophyllum brasiliense (heartwood).
118 Lichexanthone (X)	187	1	3, 6 (8-methyl)	Parmelia formosana, P. quercina.
119 Ravenelin (X)	268 (205)	1, 4, 8	(3-methyl)	Metabolite of Helminthosporium ravenelii curtis and H. turcicum passerini.
120 Swertianol (X)	267 (240)	1, 3, 8	5	Swertia tosaensis, S. japonica (roots)
121 Swertinin (X)	217 (157)	1, 2	5, 6	Swertia decussata (stems)
122 Angustifolionol (C)	118	5	7(2, 6, 8-trimethyl)	Backhousia angustifolia (oil).
123 Chellol (C)	178		5 (2-hydroxymethyl- [2', 3':6, 7] -furan)	Ammi visnaga (seeds).
124 Eugenin (C)	120 (154)	5	7 (2-methyl)	Eugenia aromatica (flowers).
125 Eugenitin (C)	162 (177)	5	7 (2, 6-dimethyl)	E. caryophyllata (flowers).
126 Isoeugenitol (C)	230 (151)	5, 7	(2, 8-dimethyl)	E. caryophyllata (flowers).
127 Khellin (C)	155		5, 8 (2-methyl- [2', 3':6, 7] -furan)	Ammi visnaga (seeds).
128 Peuceenin (C)	212	5, 7	(2-methyl-6-iso-propenyl-2)	Peucedanum ostruthium (wood).
129 Visnagin (C)	145		5 (2-methyl-[2', 3':6, 7] -furan)	Ammi visnaga (seeds).
130 Aureusidin (A)	295 (185)	4, 6, 3', 4'		Antirrhinum majus, Oxalis cernua (yellow flowers).
131 Leptosidin (A)	254 (166)	6, 3', 4'	7	Coreopsis grandiflora (flowers).
132 Sulfuretin (A)	312 (194)	6, 3', 4'		Cosmos sulfureus, Dahlia variabilis (yellow flowers).

Pigment	Melting Point, °C ¹	Hydroxyl Position, C-	Optical Rotation ¹⁰	Source
Flavanonols				
133 Alpinone	178 (118)	3, 5 (7-methoxyl, 2-methyl)	+79 (pyridine) ¹¹	Nothofagus dombeyi, Prunus serotina (heartwood), Cercidiphyllum japonicum.
134 Ampelopsin	246 (175)	3, 5, 7, 3', 4', 5'		Ampelopsis meliaeifolia kudo.
135 Dihydrorobinetin	228 (143)	3, 7, 3', 4', 5'	+13.8 (acetone)	Robinia pseudoacacia (wood).
136 Fustin	218 (151)	3, 7, 3', 4'		Rhus cotinus, Quebracho Colorado (wood).
137 Katusuranin	241	3, 5, 7, 4'	+45 (acetone + water)	Cercidiphyllum japonicum, Nothofagus dombeyi, Prunus serotina.
138 Phellamuretin	220 (199)	3, 5, 4' (2'', 2''-dimethyl-[7, 8: 6'', 5'']-chromano)		Phellodendron amurense.
139 Pinobanksin	178	3, 5, 7	+14.4 (methanol)	Pinus spp (heartwood).
140 Taxifolin	242 (130)	3, 5, 7, 3', 4'	+46 (acetone + water); +13 (ethanol)	Pseudotsuga menziesii (heartwood), Larix decidua (heartwood).
141 Pinobanksin 7-methyl ether	181	3, 5 (7-methoxyl)	-20 (chloroform)	Pinus clausa (heartwood).

/1/ Values in parentheses are for the fully acetylated derivatives unless otherwise noted. /10/ Determined at 20°C unless otherwise specified. /11/ Determined at 29°C.

Part II: CHARACTERISTIC REACTIONS OF SOME FLAVONOID TYPES

Type	Cold Alkali	Hot Alkali	Concentrated H ₂ SO ₄	Ferric Chloride	Mg-HCl ¹	Lead Acetate
1 Flavones	Yellow to red-orange	Yellow to red-orange	Lemon or green yellow	Olive-green	Red-orange	Yellow ppt
2 Flavonols	Yellow	Yellow	Yellow to green and blue-green (some fluoresce)		Pink to red	Orange-yellow ppt
3 Chalcones	Red	Blue-red	Yellow to orange	Brown	No color change	Brick-red ppt
4 Aurones	Red ²	Red ²	Red ³	No color change	No color change	
5 Flavanones	Colorless	Red	Red to yellow		Red-violet to blue-violet	Very light yellow to yellow ppt

/1/ Small piece of magnesium ribbon or turnings is placed in an alcoholic solution of the compound, and a few drops of concentrated hydrochloric acid are added. /2/ Deep purple if the 6-hydroxyl position is not free (as in a methyl ether, etc.). /3/ Yellow-orange if there is no 4' substituent.

Part III: ALGAL PIGMENTS: PHYSICAL CONSTANTS

Pigment ¹	Absorption Maxima (mμ) and Specific Extinction Coefficients	Fluorescence Emission Maxima (mμ)	Molecular Weight	Isoelectric pH	Abs. max. (mμ) of Chromophore (in acid CHCl ₃)	Source
1 R-Phycocerythrin	495 (E _{sp} 5.68) 540 (E _{sp} 6.50) 565 (E _{sp} 7.92)	580	290,000	4.3	576	Ceramium rubrum; Porphyra spp
2 C-Phycocerythrin						Phormidium fragile; Nostoc sp
3 R-Phycocyanin	550 (E _{sp} 4.06) 563 (E _{sp} 6.35)	630-690	272,000	4.85	576	Ceramium rubrum; Porphyra perforata
4 C-Phycocyanin		637 (E _{sp} 9.74)	208,000	4.7	630	Lyngbya lagerheimii; Arthrospira sp

/1/ All are soluble in dilute salt solutions and precipitated by 10-20% (NH₄)₂SO₄.

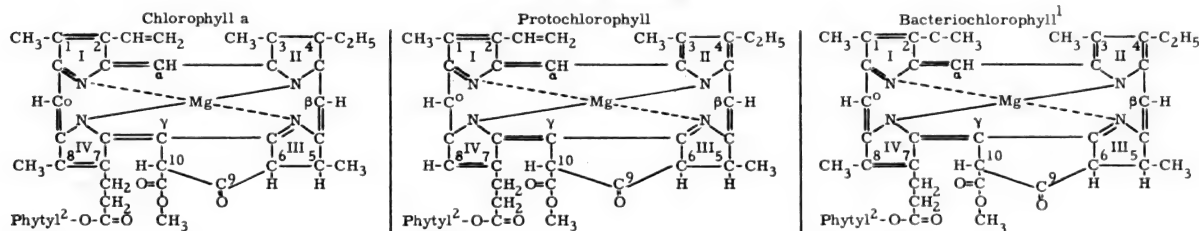
27. PLANT PIGMENTS: OCCURRENCE, PHYSICAL AND CHEMICAL CHARACTERISTICS (Concluded)

Part IV: SOME GENERAL TYPE CHARACTERISTICS

Common Name and (Type Compound)	Chemical Constitution	Molecular Formula and (Weight)	Solubility ¹	Absorption Maxima ¹ mμ	Source
Carotenoids					
1 Beta-carotene	[1,19-Di-(β-iono)-3,7,12,16-tetramethyl-octo-deca-noene-2,4,6,8,10,12,14,16,18]-polyene	C ₄₀ H ₅₆ (536)	s.CS ₂ , chl., bz.	520, 485, 450 in CS ₂ ; 497, 466 in chl.	Widely distributed in plants together with chlorophyll and xanthophyll.
2 Xanthophyll	[1-(3-Hydroxy-β-iono)-3,7,12,16-tetramethyl-octo-deca-noene-2,4,6,8,10,12,14,16,18]-polyene	C ₄₀ H ₅₆ O ₂ (568)	s.chl., acet., eth., bz.	508, 475, 445 in CS ₂ ; 487, 456, 428 in chl.	See carotene above.
Diaryl Methane					
3 Curcumin ²	1,7-Di(4-hydroxy-3-methoxyphenyl)-heptadiene-1,6-dione-3,5	C ₂₁ H ₂₀ O ₆ (368)	s.eth.	425 ³ in al. ⁴ ; 667, 625, 615, 385, 294 (solid state).	→Roots, shoots of Curcuma tinctoria.
Carbocyclic Compounds					
4 Atromentin (Benzoquinone)	2,5-Di(p-hydroxyphenyl)-3,6-dihydroxy-1,4-benzoquinone	C ₁₈ H ₁₂ O ₆ (324)	s.al., amyl alc., eth.	No characteristic absorption spectrum.	→Fungus Paxillus atromentous.
5 Vitamin K ₁ (Naphthoquinone)	2-Methyl-(3,7,11,15-tetramethylhexadecene-2)-naphthoquinone-1,4	C ₃₁ H ₄₆ O ₂ (324)	s.eth., acet., hexane	325, 270, 260, 249, 243 in hexane.	→Leaves of plants; microorganisms.
6 Alizarin (Anthracene)	1,2-Dihydroxyanthraquinone	C ₁₄ H ₈ O ₆ (240)	s.al., eth., bz.	388, 250 ³ in al.	→Roots of Olenlandia umbellata.
7 Telephoric acid (Phenanthrene)	(3,4'-Dihydroxy-3'-carboxyl-5,6'-dione-4,1'-diphenyl)-1-(2,4-pentadienolic acid)	C ₂₀ H ₁₂ O ₉ (396)	s.pyr.	495 in pyr.	→Various spp of Telephora.
Heterocyclic Compounds Containing Heterocyclic Oxygen					
8 Usnic acid (five-membered ring)	[(Phenyl-1-[ethanone-1]-2,4-dihydroxy-3-methyl)-[furyl-5,6]-2-methyl-3-hydroxy-4-[ethanone-1]-5-carbonyl)-cyclohexadiene-3,6	C ₁₈ H ₁₆ O ₇ (344)	s.al., eth., bz.	Not available.	→Various spp of Usnea, Pamelia, Leganora.
9 Flavone (six-membered ring)	2-Phenyl-chromone	C ₁₅ H ₁₀ O ₂	s.al., eth., w.	298, 250 in al.	→Leaves, flower stems, seed capsules of some Primulæ spp.
10 Polargonidin ⁵ (six-membered ring)	3,5,7,4'-Tetrahydroxy-flavone	C ₁₅ H ₁₁ O ₅	s.ac.a., al., butanol	500, 420 ³ in w.; 530, 420 ³ in al.	→Asters and carnations.
Compounds Containing Heterocyclic Nitrogen					
11 Indigo (Indole)	1,2-Di-(3-carbonyl-2-indole)-ethene	C ₁₆ H ₁₀ O ₂ N ₂ (262)	s.h.chl., h. aniline	591 in xylol.	Various spp of Indigofera; Polygonum tinctorium.
12 Chlorophyll a (Pyrrole)	Mg-complex of 1,3,5,8-tetramethyl-4-ethyl-2-vinyl-9-oxo-10-carbomethoxy-phorbine-7-propionic acid-phytyl-ester	C ₅₅ H ₇₂ O ₅ N ₄ Mg·½H ₂ O (901)	s.eth., acet., me.alc.	See table below.	Chloroplasts of green plants.
13 Leghemoglobin (Pyrrole)	Iron complex of globin and 1,3,5,8-tetramethyl-2,4-divinyl-porphin-6,7,7-dipropionic acid	C ₃₄ H ₃₂ O ₄ ·N ₄ Fe globin (17000)	s.w.	555, 485 in w.	Root nodules of leguminous plants.

/1/ Abbreviations: ac. a. = acetic acid; acet. = acetone; al. = ethanol (95%); alc. = alcohol; bz. = benzene; chl. = chloroform; eth. = ether; h. = hot; me. = methyl; pyr. = pyridine; s. = soluble; w. = water. /2/ Indian saffron. /3/ Read from absorption curve. /4/ Undergoes changes in solution. /5/ Occurs as the 3-galactoside.

Part V: CHLOROPHYLLS



Pigment	Absorption Maxima ³		Fluorescence Maxima ³		Principal Source	Remarks
	In Ether mμ	Phaeophytin ⁴ in Ether mμ	In Ether mμ	Phaeophytin ⁴ in Ether, mμ		
1 Chlorophyll a	660, 617, 575, 430, 410.	668, 612, 564, 543, 506, 412.	668, 723	672.5, 715	All photosynthetic tissues except photosynthetic bacteria.	
2 Chlorophyll b	640, 595, 535, 455.	655, 600, 545, 525, 436.	649, 708.	657, 707	Photosynthetic tissues of higher plants, ferns, mosses, chlorophyceae, (green algae) Euglenineae and some diatoms(?).	When present, represents about 20-40% of the total chlorophylls.
3 Chlorophyll c (Chlorofucin)	627, 579.5, 545, 446.	640, 595, 565, 525, 420.	629, 690.	649, 719.	Diatoms, dinoflagellates, (Dinophyceae) and brown algae (Phaeophyceae).	Probably phytol-free.
4 Chlorophyll d	686, 645, 595, 545, 445, 390.	590, 636, 545, 520, 425, 380.	696, 752.	701.	Red algae especially (Rhodochorton nothii).	Contains phytol residue and the cyclopentanone ring.
5 Chlorophyll e	654, 415 (in methanol).				Yellow-green algae (Tribonema bombycinum).	
6 Protochlorophyll	623, 571, 535, 432.		627, 685 (in acetone)		Etiolated seedlings.	Probable precursor of the chlorophylls.
7 Bacteriochlor-	770, 708, 574, 390, 365.	754, 686, 612, 528, 492, 385, 367.			All purple sulfur and non-sulfur photosynthetic bacteria.	
8 Chlorobium Chlorophyll (Chloroviridin)	764, 659, 624, 431, 408.	760, 660, 604, 549, 515, 412			Green sulfur photosynthetic bacteria (Chlorobium spp).	Not identical with bacterio-chlorophyll.

/1/ Structure is still tentative. /2/ Phytol = (CH₃)₂-CH(CH₂)₃-CH-(CH₂)₃-CH(CH₂)₃-C=CH-CH₂OH. /3/ Principal maxima underlined. /4/ The magnesium-free pigment.

28. PLANT RESINS: SOURCE, PHYSICAL AND CHEMICAL CHARACTERISTICS
Data are approximations and may vary depending upon the history of the sample.

Substance	Source	Specific Gravity	Softening Point, °C	Melting Point, °C	Acid Number	Saponification Number	Iodine Number	Solvent
1 Accra copal	Copaifera sp	1.033	75	120	98	140	58	Amyl alcohol, aniline
2 Accroides	Xanthorrhoea spp	1.34	75	110	64-106	65	200	Alcohol, esters, ketones
3 Amber	Fossils of Pinaceae	1.05-1.10	175	250-315	15-35	85-150	62	Turpentine oil, CS ₂
4 Animé copal	Fossils	1.03		230	18-27	60-90	128-137	
5 Benguela copal	Copaifera demeusei	1.06	65	165	123	157	61-85	Amyl alcohol, aniline
6 Benzoin ¹	Storax (Styrax benzoin)	1.09		>100	75-100	190-207	57-76	Ethyl alcohol, acetone
7 Borea manila	Agathis alba ¹	1.07	79-80	130-132	118-141	143-175	110-137	Ethyl alcohol, ketones
8 Brazil copal	Hymenaea courbaril	1.053	50	100	123	133	123-134	Amyl alcohol, aniline
9 Cameron copal	Copaifera demeusei	1.052	100	150	160	70	65-70	Aniline, ether
10 Colombia copal	Hymenaea spp	1.054	90	<300	119	156		Amyl alcohol, aniline
11 Congo copal	Copaifera demeusei	1.06	90	128	100	124	115	Amyl alcohol, amyl acetate, aniline
12 Damar, Batavia	Shorea spp, Hopea spp	1.03-1.06	70-76	99-110	22-23	29-39	95-127	Chloroform, benzene
13 Demerara copal	Hymenaea courbaril	1.047	90	180	98	102		Ether ² , chloroform ² , aniline ²
14 Dragon's blood	Daemonorhops draco	1.25		100	11	153	54-98	Alcohol, ether, benzene
15 Elemi, Manila	Canarium luzonicum	1.02-1.05		75	20-35	21-44	118	Esters
16 Guaiacum	Guaiacum officinale	1.2		85-90	20-53	74-84		Ether ³
17 Jalap	Exogonium purga	1.14		150	12-27		132	Ethyl alcohol
18 Kauri, pale	Kauri-pine (Agathis australis)	1.05	90-130	127-134	57-81	67-117	82-154	Amyl alcohol, aniline
19 Kissel copal	Copaifera demeusei	1.066	65	110	70	118		Aniline
20 Madagascar copal	Trachylobium verrucosum	1.056	130	300	66	78	126	Amyl alcohol ² , aniline ²
21 Manila hard	Agathis alba	1.07	79-80	130-132	118-141	143-175	110-137	Amyl alcohol, aniline
22 Manila soft	A. alba	1.06	77-88	121	127-134	158-190	121-126	Alcohol
23 Mastic	Pistacia lentiscus	1.04-1.07	55	76	50-70	62-90	64-124	Amyl alcohol, ether, benzene
24 Pontianak	Agathis alba	1.07-1.08	82-135	126-169	112-121	148-180	119-142	Alcohol, hydrocarbons
25 Red Angola copal	Copaifera demeusei	1.066	90	305	128	132	63-137	Amyl alcohol, acetone
26 Rosin	Pine, longleaf (Pinus palustris)	1.07-1.09	70-80	120-135	150-175	167-194	80	Organic solvents
27 Sandarac	Arara-tree (Callitris quadrivalvis)	1.05-1.09	100-130	135-150	117-155	145-157	112-141	Alcohol, ether
28 Sierra Leone copal	Copaifera copalifera	1.072	60	130	110	123	63-133	Amyl alcohol, aniline
29 White Angola copal	Copaifera demeusei	1.055	45	95	127	160	130	Amyl alcohol, acetone
30 Zanzibar copal	Trachylobium verrucosum	1.054	150	300	93	93	115-123	Amyl alcohol ² , amyl acetate ²

/1/ A balsam. /2/ Partly soluble. /3/ 54-74% solubility.

29. PLANT TANNINS: SOURCE AND CHEMICAL CHARACTERISTICS

Plant tannins are polyphenols, within plant extracts, capable of converting the collagen in hides and skins into non-putrescible leather. Varying quantities of mono- and disaccharides, gums and various phenols are associated with the tannin in the extract, but are not alone capable of forming the conversion. There are two main categories of tannins, generally but not absolutely valid: HYDROLYZABLE, hydrolyzed by HCl or enzymes into sugars and phenolic carboxylic acids, and CONDENSED, converted by hot HCl into more highly condensed and insoluble red "phlobaphenes" or tanners' red, constitution unknown.

Part I: HYDROLYZABLE TANNINS

Tannin ¹	Empirical Formula	Source	Present in Commercial Extract	Constitution and Hydrolysis Products
1 Acertannin	C ₂₀ H ₂₀ O ₁₃ ·2H ₂ O	Acer ginnala (leaves)		Digalloylceritol 2 gallic acid + aceritol
2 Brevilagin		Caesalpinia brevifolia (pods)	Algarobilla (brevifolin carbonic acid)	Glucose + ellagic acid + C ₁₃ H ₈ O ₈
3 Chebulagic acid	C ₄₁ H ₃₀ O ₂₇ ·10H ₂ O	Terminalia chebula (fruit)	Myrobalan and divi-divi	Glucose + gallic acid + ellagic acid + chebulic acid (C ₁₄ H ₁₂ O ₁₁)
4 Chebulinic acid	C ₄₁ H ₃₂ O ₂₇ ·2H ₂ O	Terminalia chebula (fruit)	Myrobalan	Glucose + 3 gallic acid + chebulic acid (C ₁₄ H ₁₂ O ₁₁)
5 Corilagin	C ₂₇ H ₂₂ O ₁₈	Terminalia chebula (fruit)	Myrobalan and divi-divi	Glucose + gallic acid + ellagic acid
6 Dehydrodigallic acid	C ₁₄ H ₁₀ O ₁₀	Castanea vesca (leaves, shoots ²)		Gallic acid
7 Ellagic acid	C ₁₄ H ₆ O ₈	Quercus sp ³ (galls)	Divi-divi, algarobilla, myrobalan, valonia, chestnut	4, 5, 6, 4', 5', 6', -Hexahydroxy-diphenic acid - 8,8-dilactone
8 Hamamel tannin	C ₂₀ H ₂₀ O ₁₄ ·6H ₂ O	Hamamelis virginiana (bark)		Digalloylhamamelose 2 gallic acid + hamamelose
9 Tannic acid ⁴	C ₇₆ H ₅₂ O ₄₆	Rhus chinensis (galls)	Chinese tannin	Glucose + 10 gallic acid
10 Valonia acid dilactone	C ₂₁ H ₁₀ O ₁₃	Quercus aegilops ⁵ (acorn cups)	Valonia	Ellagic acid + gallic acid

/1/ Except where indicated, all tannins listed are crystalline. /2/ Young. /3/ Numerous other sources. /4/ Amorphous. /5/ And allied species.

Part II: CONDENSED TANNINS

Condensed tannins are composed of complex mixtures of highly condensed and probably closely related polyphenols, constitution unknown, and lower molecular polyphenolic fractions in which certain constituents are identified. These tannins comprise about 60% of solid commercial plant extracts, associated therein with varying admixtures of "non-tannins."

Extract	Source	Alkali Fusion Products	Polyphenolic Constituents	Associated Non-tannin Constituents
1 Cube Gambier	Uncaria gambier (leaves)	Phloroglucinol, protocathechuic acid	d-Catechin, di-epigallocatechin, d-epigallocatechin, quercitin	
2 Cutch	Acacia catechu (wood)	Phloroglucinol, protochechuic acid	l-Catechin, dl-catechin, l-epigallocatechin, dl-epigallocatechin, quercitin	
3 Green tea tannin	Thea sinensis (leaves)		l-Epigallocatechin, d-gallocatechin, d-catechin, l-epigallocatechin gallate, l-catechin gallate, theogallin, quercitin, kaempferol	Sucrose, glucose, fructose, maltose, arabinose, rhamnose, ribose, mesoinositol, gallic acid, anthoxanthins, theanine
4 Quebracho	Schinopsis lorentzii (heartwood)	Resorcinol, protocathechuic acid	Fisetin, ellagic acid	Glucose, arabinose, xylose, gallic acid
5 Wattle (Mimosa)	Acacia mollissima (bark)	Resorcinol, gallic acid; protocathechuic acid, β-resorcylic acid, pyrogallol, phloroglucinol, catechol	Catechin, gallocatechin, fisetin	Sucrose, glucose, fructose, gums

30. ESSENTIAL OILS, PLANT: SOURCE, PHYSICAL AND CHEMICAL CHARACTERISTICS

Essential Oil (Botanical Source) Geographical Source	Plant Part, Yield ¹ g/100 g	Properties ²	Chemical Constituents ³	Essential Oil (Botanical Source) Geographical Source	Plant Part, Yield ¹ g/100 g	Properties ²	Chemical Constituents ³
1 Almond, bitter (<i>Prunus amygdalus</i>) France, Italy, Spain	Dried, ripe, defatted seed (0.5-0.7)	Sp gr = 1.042-1.07 $\alpha_D = 0.0$ to $+0.17$ $n_D = 1.532 - 1.544$	Benzaldehyde*, hydrocyanic acid, benzaldehyde cyanohydrin	112 Lemongrass, East Indian 113 type (<i>Cymbopogon</i> 114 flexuosus) India	Grass (0.2-0.4)	Sp gr = 0.899-0.911 $\alpha_D = +1.5$ to -5 $n_D = 1.483 - 1.4899$	Citral*
4 Anise seed (<i>Pimpinella anisum</i>) Russia, Germany, France	Dried, ripe fruit (1.9-3.1)	Sp gr = 0.984-0.994 $\alpha_D = -2$ to $+1$ $n_D = 1.5530-1.5600$	Acetaldehyde, p-methoxyphenyl- acetone, anethole*, methyl chavicol	115 Lemongrass, Java type 116 (<i>Cymbopogon citratus</i>) W. 117 Indies, Madagascar, Honduras	Shoots (0.2-0.4)	Sp gr = 0.875-0.900 $\alpha_D = -3$ to $+1$ $n_D = 1.4830-1.4890$	Myrcene*, geraniol, nerol, α - and β -citral*, methyl heptenone
7 Anise, star (<i>Illicium verum</i>) China	Fruit (2.5-3.0)	Sp gr = 0.98-0.995 $\alpha_D = +0.6$ to -4.08 $n_D = 1.553 - 1.5582$	d- α -Pinene, anisaldehyde, p-methoxyphenylacetone, ane- thole*, methyl chavicol	118 Lime, acid, distilled (<i>Citrus</i> 119 aurantifolia) E. and W. 120 Indies, Florida, Mexico	Fruit (0.3-0.4) ⁴	Sp gr = 0.855-0.8635 $\alpha_D = +34$ to $+47$ $n_D = 1.4745 - 1.4770$	Bisabolene, d-limonene*, borneol, l- α -terpineol, n-decylaldehyde, lauric aldehyde, n-octylaldehyde
10 Basil, sweet (<i>Ocimum</i> 11 basilicum) France, 12 Germany, Algeria, Spain	Flowering shoots (0.09-0.11)	Sp gr = 0.896-0.935 $\alpha_D = -7.0$ to -13.87 $n_D = 1.477-1.495$	Linalool, methyl chavicol*, cineole	121 Linolee 122 (<i>Bulsera delpechiana</i>) 123 Mexico	Wood (6-11)	Sp gr = 0.875-0.8981 $\alpha_D = -14$ to $+8.2$ $n_D = 1.460-1.466$	l-Linalool*
13 Bergamot (<i>Citrus auran-</i> 14 <i>tium bergamia</i>) 15 W. Africa, Italy	Fruit rind (0.5) ⁴	Sp gr = 0.881-0.887 $\alpha_D = +8.0$ to $+24.27$ $n_D = 1.464-1.468$	d-Limonene, l-linalool, nerol, l-linalyl acetate*, bergaptenes, bergaptenol	124 Mandarin 125 (<i>Citrus reticulata</i>) 126 Florida, W. Indies, Sicily	Fruit (0.75-0.85)	Sp gr = 0.854-0.859 $\alpha_D = +64$ to $+75$ $n_D = 1.4745-1.478$	Limonene
16 Birch, sweet 17 (<i>Betula lenta</i>) 18 Canada, U.S.A.	Twigs (1.2-1.9)	Sp gr = 1.184-1.190 α_D Inactive $n_D = 1.5350-1.5380$	Triacetonate (?)($C_{30}H_{62}$), methyl salicylate*, an ester ($C_{14}H_{24}O_2$)	127 Mint 128 (<i>Mentha arvensis</i>) 129 Japan, China, Brazil	Entire plant (1.3-1.6)	Sp gr = 0.895-0.909(?) $\alpha_D = -29$ to -43 (?) $n_D = 1.459-1.465$ (?)	l-Limonene, l-menthol*, isomenthone, l-menthone, l-menthyl acetate
19 Bois de Rose (<i>Aniba</i> 20 <i>rosaedora</i>) French 21 Guiana, Brazil	Wood (0.7-1.2)	Sp gr = 0.875-0.895 $\alpha_D = -4$ to $+5$ $n_D = 1.4620-1.4685$	Linalool*, dipentene, terpineol, nerol, geraniol, p-methylaceto- phenone, cineole	130 Myrtle (<i>Myrtus communis</i>) 131 Southern France, Algeria, 132 Spain, Asia Minor	Leaves (0.18-0.25)	Sp gr = 0.881-0.929 $\alpha_D = +15$ to $+27.5$ $n_D = 1.464 - 1.4703$	Cineole, l-myrtanol, d-myrtanol (as ester)*
22 Cade 23 (<i>Juniperus oxycedrus</i>) 24 France, Spain	Wood (1.2-1.3)	Sp gr = 0.956-1.061 $\alpha_D = +4.3$ to $+4.7$ (?) $n_D = 1.511-1.514$ (?)	d-Cadinene*, d-cadinol, creosol, guaiacol	133 Nutmeg (<i>Myristica fragrans</i>) 134 E. and W. Indies, Ceylon, 135 Indonesia	Dried, ripe seed (5-16)	Sp gr = 0.861-0.917 $\alpha_D = +8$ to $+45$ $n_D = 1.4690-1.4880$	α -Pinene*, borneol, geraniol, d-linalool, myristicin, safrole, eugenol, d-camphene*
25 Calamus (<i>Acorus</i> 26 calamus) Europe, Asia, 27 North America	Rhizomes (1.5-4.8)	Sp gr = 0.950-1.083 $\alpha_D = -0.9$ to $+31$ $n_D = 1.5013-1.5522$	Asarone*	136 Orange, bitter (<i>Citrus</i> 137 <i>aurantium amara</i>) 138	Fruit rind (0.15-0.33)	Sp gr = 0.845-0.8525 $\alpha_D = +87$ to $+96.5$ $n_D = 1.4730-1.4770$	Limonene*, linalool, d- α - terpineol, decylaldehyde, acetic acid, cinnamaldehyde
28 Camphor 29 (<i>Cinnamomum camphora</i>) 30 Formosa, China	Wood (1.0-3.0)	Sp gr = 0.9545 $\alpha_D = +32.4$ (?) $n_D = 1.4806$ (?)	α -Pinene, β -pinene, l-linalool, camphor*, 1,8-cineole, 1,4- cineole, safrole	139 Orange, sweet (<i>Citrus</i> 140 <i>sinensis</i>) Portugal, Florida, 141 California, Sicily	Fruit rind (0.1-0.7) ⁴	Sp gr = 0.842-0.8465 $\alpha_D = +94$ to $+99.5$ $n_D = 1.4723-1.4737$	d-Limonene*, linalool, decylaldehyde, citral
31 Caraway 32 (<i>Carum carvi</i>) 33 Holland, Asia	Dried, ripe seed (3-6)	Sp gr = 0.907-0.919 $\alpha_D = +70$ to $+81$ $n_D = 1.484-1.488$	d-Limonene, carveol, carvone*, dihydrocarvone, d-dihydropinol	142 Origanum 143 (<i>Coridothymus capitatus</i>) 144 Spain	Fresh plant (0.9)	Sp gr = 0.917-0.955(?) $\alpha_D = \pm$ to $+1$ (?) $n_D = 1.499-1.508$	p-Cymene, d- α -pinene, a sesquiterpene, carvacrol*, thymol
34 Cardamon (<i>Elettaria car-</i> 35 <i>damomum</i> var. α -major) 36 Southern India, Ceylon	Seeds (3-8.6)	Sp gr = 0.923-0.940 $\alpha_D = +20$ to $+41$ $n_D = 1.461-1.467$	Cineole*, terpineol, terpinyl acetate, limonene, sabinene(?)	145 Palmrosa 146 (<i>Cymbopogon martini</i> var. 147 <i>motia</i>) India	Grass (1-1.25)	Sp gr = 0.887-0.900 $\alpha_D = +6$ to -3 $n_D = 1.4685-1.4790$	Geraniol*, farnesol, citral, citronellal, formaldehyde, acetic acid
37 Cassia 38 (<i>Cinnamomum cassia</i>) 39 China	Leaves, twigs (0.3-0.8)	Sp gr = 1.051-1.069 $\alpha_D = -1$ to $+1$ $n_D = 1.6020-1.6135$	Cinnamaldehyde*, o-methoxy- benzaldehyde, methyl-o-coumaral- dehyde, cinnamylacetate, coumarin	148 Patchouly 149 (<i>Pogostemon cablin</i>) 150 Java, Singapore	Dried leaves (3.0)	Sp gr = 0.950-0.991 $\alpha_D = -40$ to -72 $n_D = 1.5060-1.5160$	Patchouly alcohol, azulene, benzaldehyde, cinnamaldehyde, eugenol
40 Catnip 41 (<i>Nepeta cataria</i>) 42 Sicily, U.S.A.	Entire plant (0.3)	Sp gr = 0.986-1.083 $\alpha_D = +1.3$ to $+13.3$ $n_D = 1.4872-1.4913$	Nepatalic acid*	151 Pennyroyal 152 (<i>Mentha pulegium</i>) 153 Spain, Morocco	Entire plant (1.0)	Sp gr = 0.936-0.982(?) $\alpha_D = +15$ to $+24$ (?) $n_D = 1.483-1.494$ (?)	l- α -Pinene, menthol, l-menthone, d-pulegone*, piperitone, 3-octanyl acetate
43 Cedarwood 44 (<i>Juniperus virginiana</i>) 45 North America	Heartwood (2-3)	Sp gr = 0.945-0.960 $\alpha_D = -27$ to -45 $n_D = 1.5020-1.5070$	Cedrene*, cedrenol, cedrol, pseudocedrol	154 Pepper 155 (<i>Piper nigrum</i>) 156 India	Berries (1-3.2)	Sp gr = 0.873-0.916 $\alpha_D = +3$ to -16 $n_D = 1.480-1.499$	β -Caryophyllene, dl-limonene, l- α -phellandrene, α -pinene, piperonal
46 Celery seed 47 (<i>Apium graveolens</i>) 48 Europe, India	Seed (1.9-2.5)	Sp gr = 0.878-0.916 $\alpha_D = +48$ to $+78$ $n_D = 1.4800-1.4900$	d-Limonene*, sedanoic anhydride, sedanolid, selenine, palmitic acid, guaiacol(?)	157 Peppermint 158 (<i>Mentha piperita</i>) 159 North America, Europe	Entire plant (0.3-1.0)	Sp gr = 0.901-0.913 $\alpha_D = -18$ to -32 $n_D = 1.4590-1.4650$	l-Menthol*, d-menthone, l-menthone, menthofuran, dimethyl sulfide
49 Cinnamon 50 (<i>Cinnamomum zeylanicum</i>) 51 Ceylon	Dried bark (0.2)	Sp gr = 1.016-1.036 $\alpha_D = 0$ to -2 $n_D = 1.5730-1.5910$	Caryophyllene, l- α -pinene, l-linalool, cinnamaldehyde*, cinnamaldehyde, eugenol	160 Perilla 161 (<i>Perilla frutescens</i>) 162 Japan	Blossoms, leaves (0.1-0.15)	Sp gr = 0.923-0.938 $\alpha_D = -73$ to -96.5 $n_D = 1.4971-1.5048$	Perillaldehyde*
52 Citronella 53 (<i>Cymbopogon nardus</i>) 54 Ceylon	Dried grass (0.5)	Sp gr = 0.898-0.910 $\alpha_D = -9$ to -18 $n_D = 1.4790-1.4855$	Geraniol*, citronellol, camphene, limonene, l-borneol, farnesol, methyl eugenol	163 Pimenta berry (<i>Pimenta</i> 164 <i>officinalis</i>) 165 Jamaica	Fruit (3.3-4.3)	Sp gr = 1.025-1.055 $\alpha_D = 0$ to -4 $n_D = 1.5270-1.5400$	Caryophyllene, eugenol*, eugenol methyl ether, cineole
55 Citronella 56 (<i>Cymbopogon winterianus</i>) 57 Java	Shoots (0.5-2.4)	Sp gr = 0.882-0.901 $\alpha_D = -0.47$ to -5.75 $n_D = 1.463-1.475$	Geraniol*, citronellol, cadinol, d-citronellal, methyl eugenol, geranyl butyrate	166 Pine, dwarf 167 (<i>Pinus mugo</i>) 168 Austrian Tyrol	Twigs, leaves (0.3-0.6)	Sp gr = 0.859-0.877 $\alpha_D = -5$ to -15.5 $n_D = 1.4750-1.4800$	Pinene, limonene, dipentene, borneol, ketones, phenols

58 Clove (Eugenia caryophyllata)	Dried, unopened buds (15.5-17)	Sp gr = 1.043-1.068 α_D = -1 to -1.58 n_D = 1.5270-1.5350	Caryophyllene, furfural, eugenol*, vanillin, methyl salicylate and benzoate	169 Rose (Rosa damascena)	Flowers (0.02)	Sp gr = 0.848-0.8636 α_D = -1 to -4 n_D = 1.4570-1.46306	Stearoptenes, 1-citronellol*, geraniol, 1-linalool, nerol, phenylethyl alcohol
60 Madagascar, Zanzibar	Seeds (0.15-1.1)	Sp gr = 0.870-0.885 α_D = +4 to +13 n_D = 1.463-1.471	Linalool*, p-cymene, 1-borneol, geraniol, n-decylaldehyde, acetic acid, decylic acid	171 Bulgaria, Turkey	Entire plant (0.4-0.7)	Sp gr = 0.901-0.919 α_D = -5 to +10 n_D = 1.4640-1.4760	α -Pinene, borneol, camphor, bornyl acetate, cineole
62 Coriander (Coriandrum sativum)	Berries (10-20)	Sp gr = 0.909-0.930 α_D = -12.5 to -46 n_D = 1.4919-1.4981	Cubeb camphor, terpenes	172 Rosemary (Rosmarinus officinalis)	Leaves (0.7-2.0)	Sp gr = 0.909-0.931 α_D = +2 to +9 n_D = 1.4570-1.4690	d- α -Pinene, salvene (C ₁₀ H ₁₈), borneol, d-camphor, d- β -thujone*, 1- α -thujone*, cineole
64 Cubeb (Piper cubeba)	Entire plant (0.3-1.5)	Sp gr = 0.890-0.906 α_D = +84 to +95 n_D = 1.4800-1.4850	a-Pinene, terpinene, carvone, d-phellandrene*, limonene	174 Mediterranean	Wood (1.4-2.6)	Den. = 0.969-0.9767 α_D = -3 to -10 n_D = 1.498-1.508	a-Santalol*
66 Java, Singapore	Shoots (0.35)	Sp gr = 0.900-0.966(?) α_D = +1.9 to +9(?) n_D = 1.504-1.520(?)	Phellandrene (?), p-methoxycinnamaldehyde, methyl chavicol*	178 Sandalwood (Eucarya spicata)	Wood, roots (4.5-6.2)	Sp gr = 0.965-0.980 α_D = -15 to -20 n_D = 1.500-1.5100	Santene, a-santalol*, β -santalol*, santalene, santalic acid, a- and β -santalenes
68 Dill weed (Anethum graveolens) Europe, North America, Hungary	Leaves (1.5-2.5)	Sp gr = 0.922-0.930 α_D = +0.5 to +2 n_D = 1.458-1.462	p-Cymene, 1,8-cineole*	180 Australia	Roots (1.8)	Sp gr = 1.072-1.084 α_D = +2 to +4 n_D = 1.5250-1.5350	Phellandrene, a-pinene, d-camphor, saffrole*, eugenol
70 Estragon (Artemisia dracunculus) U.S.A., Southern France	Seeds (1-6)	Sp gr = 0.959-0.980 α_D = +12 to +24 n_D = 1.528-1.5380	Camphene, d-a-phellandrene, anisaldehyde, d-fenchone, anethole*, methyl chavicol	181 Sandalwood (Santalum album)	Entire plant (0.7)	Sp gr = 0.923-0.940 α_D = -48 to -59 n_D = 1.4840-1.4910	1-Phellandrene, dihydrocarveol, 1-carvone*, (1-linalool*, cineole in Russian variety).
72 Eucalyptus (Eucalyptus polybractea)	Shoots (0.15)	Sp gr = 0.889-0.904 α_D = -7 to -14 n_D = 1.4629-1.4720	1-a-Pinene, sesquiterpenes, citronellol*, sesquiterpene alcohols, 1-isomenthone, formic esters	182 Southern India	Leaves (0.2)	Sp gr = 0.874-0.888 α_D = -20.6 to -40 n_D = 1.474-1.478	a-Pinene, β -pinene, bornyl acetate, dipentene cadinene
74 Australia	Dried rhizomes (1.5-3.0)	Sp gr = 0.877-0.888 α_D = -28 to -45 n_D = 1.4880-1.4940	d-Camphene, d- β -phellandrene, d-borneol, zingiberol, citral, cineole, zingiberene	183 U.S.A.	Fruit (0.1)	Sp gr = 0.850-0.856 α_D = +90.7 to +93.5 n_D = 1.4732-1.4750	Limonene*
76 Fennel, bitter (Foeniculum vulgare) France, Italy, India, Russia	Grass (1-1.25)	Sp gr = 0.900-0.953 α_D = +54 to -30 n_D = 1.4780-1.4930	Geraniol*	184 Sassafras (Sassafras albidum)	Herbs (0.2-0.5)	Sp gr = 0.916-0.9409 α_D = -6.3 to +38.8 n_D = 1.4456-1.4707	β -Thujone*
78 Geranium (Pelargonium spp) Algeria, Reunion	Peel (0.06)*	Sp gr = 0.855-0.860 α_D = +91 to +965 n_D = 1.4750-1.4780	Limonene*, linalool, citral, decylaldehyde, octylaldehyde, umbelliferone	186 U.S.A.	Flowering plant (0.7-2.6)	Sp gr = 0.916-0.941 α_D = -0.27 to -3.2 n_D = 1.495-1.505	Camphene, caryophyllene, β -pinene, 1-borneol, carvacrol, thymol*
80 U.S.A., Brazil	Wood (2.7-5.4)	Sp gr = 0.973-0.985 α_D = -3 to -12.3 n_D = 1.502-1.508	Guaiac, buinesol	188 (Mentha spicata)	Flowers (0.08)	Sp gr = 1.009-1.035 α_D = -2.5 n_D = 1.5136-1.5352	Methyl salicylate and anthranilate, methyl and benzyl benzoates
82 Ginger (Zingiber officinale) Asia, West Indies, Africa	Leaves, blossoms (0.15-0.8)	Sp gr = 0.9237-0.956 α_D = -15.7 to -19.3 n_D = 1.4783-1.4829	1-Pinocamphone*	189 North America	Oleoresin (20)	Sp gr = 0.860-0.874 α_D = +15(?) n_D = 1.4680-1.4780	d-a-Pinene*, 1- β -pinene, terpinolene, pinocarveol, methyl chavicol
84 West Indies, Africa	Flowers (0.17)	Sp gr = 0.993-1.047 α_D = +2.2 to +3.7 n_D = 1.4944-1.5015	Benzyl acetate*, 1-linalool	190 Spruce (Picea excelsa)	Roots (1.5-2.0)	Sp gr = 0.9852-1.058 α_D = +14 to +45 n_D = 1.510-1.5306	Vetivonols*, a- and β -vetivones, benzoic and palmitic acids
86 Gingergrass (Cymbopogon martinii var. sofia) India	Fruit (0.8-1.6)	Sp gr = 0.860-0.879 α_D = 0 to -15 n_D = 1.4740-1.4840	a-Pinene, borneol(?), geraniol(?), 1-terpinen-4-ol(?)	191 (Picea excelsa)	Leaves (0.5-0.7)	Sp gr = 1.184-1.190 α_D = -0.4 to -1.5 n_D = 1.5350-1.5380	Methyl salicylate*, an ester (C ₁₄ H ₂₄ O ₂), triacontane
88 Grapefruit (Citrus paradisi)	Leaves, flowers (0.3-0.9)	Sp gr = 0.882-0.895 α_D = -3 to -10 n_D = 1.4590-1.4700	a-Pinene, d-borneol, geraniol, lavandulol, 1-linalool, 1-linalyl acetate*, coumarin	192 Norway	Dried plant (1-2)	Den. = 0.937-0.9908 α_D = -0.1 to -12.5 n_D = 1.4741-1.4778	Ascaridole*, p-cymene, 1-limonene, a-terpinene, d-camphor, butyric acid
90 U.S.A., Brazil	Leaves, flowers (1-1.8)	Sp gr = 0.884-0.897 α_D = -2 to -6 n_D = 1.4610-1.4650	Linalool*, linalyl acetate*, d-borneol, d-camphor, d-camphene, cineole	193 Tangerine (Citrus reticulata)	Shoots (0.3-0.4)	Sp gr = 0.884-0.9545(?) α_D = (?) n_D = 1.460-1.483(?)	An azulene, phellandrene, thujyl alcohol, a-thujone*, β -thujone, thujyl acetate
92 Guaiac wood (Guaiacum officinale)	Fruit (0.3-0.6)*	Sp gr = 0.849-0.855 α_D = +57 to +65.65 n_D = 1.4738-1.4755	d-Limonene*, geraniol, linalool, citral*, cadinene, bisabolene	194 (Citrus reticulata)	Flowers (1.8-2.6)	Sp gr = 0.956-0.991 α_D = -23 to -43 n_D = 1.4960-1.5050	d-Caryophyllene, d-a-pinene, benzyl alcohol, acetate and benzoate, methyl benzoate*
94 Hyssop (Hyssopus officinalis)				195 Java, W. Indies, Florida			
96 Mediterranean region, France				196 Tansy (Tanacetum vulgare)			
98 (Jasminum officinale)				197 (Tanacetum vulgare)			
100 Juniper berry (Juniperus communis)				198 England, France, U.S.A.			
102 Central Europe				199 Thyme (Thymus vulgaris)			
103 Lavender (Lavandula officinalis)				200 (Thymus vulgaris)			
105 France				201 Spain			
106 Lavandin (Lavandula hybrida)				202 Tuberosa (Polyanthes tuberosa)			
107 (Lavandula hybrida)				203 France			
108 Southern France				204 France			
109 Lemon (Citrus limon)				205 Turpentine gum, American (Pinus palustris)			
110 (Citrus limon)				206 (Pinus palustris)			
111 Italy, Spain, U.S.A.				207 U.S.A.			
				208 Vetiver (Vetiveria zizanioides)			
				209 India, Burma			
				210 Wintergreen (Gaultheria procumbens)			
				211 North America			
				212 Wormseed, American (Chenopodium ambrosioides)			
				213 C.America, W.Indies, U.S.A.			
				214 Wormwood (Artemisia absinthium)			
				215 Europe, North America			
				216 Ylang ylang (Canarium odoratum) Philippines, Java, and other areas			

/1/ Plant from which oil is obtained, followed in parentheses by yield of oil, expressed as g per 100 g plant material. /2/ Sp gr = specific gravity; den. = density; α_D = optical rotation; n_D = refractive index. Values for specific gravity are calculated to 15°C ; those for n_D are reported at 20°C . /3/ For most of the oils listed these constituents are only a few of those that have been identified. An asterisk immediately following a constituent indicates that constituent is present in the greatest amount and/or most important organoleptically or for commercial uses. /4/ Method of production is by expression of specified material. /5/ Determined at 25°C . /6/ Determined at 30°C . /7/ Calculated to 15°C . /8/ Determined at 25°C and referred to water at the same temperature.

31. NATURAL TEXTILE FIBERS: PHYSICAL AND CHEMICAL CHARACTERISTICS

Fiber	Specific Gravity	Fiber Length cm	Fiber Diameter μ	Tensile Strength kg/sq mm	Tenacity g/Grex ¹	Ultimate Elongation %	Young's Modulus dynes/sq cm ²	Initial Young's Modulus g/den ¹	Stiffness g/Grex ¹	Density g/cu cm
1 Abaca (<i>Musa textilis</i>)	1.48-1.50	150-350	14-35	40.7	5.0	2.2-3.8			175	1.50
2 Banana (<i>M. paradisiaca sapientum</i>)										
3 Cotton, Egyptian (<i>Gossypium peruvianum</i>)	1.54	3.6	16.4	44	3.8	7		74		1.55
4 Cotton, Sea Island (<i>G. barbadense</i>)	1.54	2.8-3.6	9.5	68	5.3	7		33-36		1.55
5 Cotton, Upland (<i>G. hirsutum</i>)	1.54	0.6-6.25	18	37-76	2.0-5.0	7	5.9	49-54	57	1.55
6 Coir (<i>Cocos nucifera</i>)		21	18							
7 Flax (<i>Linum usitatissimum</i>)	1.50	15.2-92	15	76	5.5	1.6	36		270	1.50
8 Green hemp (<i>Crotalaria tenuifolia</i>)										
9 Hemp (<i>Cannabis sativa</i>)	1.49	92-183	18-23	84	4.0	3-5	5.1		200	1.50
10 Henequen (<i>Agave fourcroydes</i>)		75-112	17.6-17.9		3.0	3.5-4.5				
11 Jute (<i>Chorchorus</i> sp)	1.49	150-360	15.5	41	2.8	0.8	4.5-13.8		185	1.50
12 Kenaf (<i>Hibiscus cannabinus</i>)		165	24	22						
13 Mauritius hemp (<i>Fourcraea gigantea</i>)										
14 Musk-dana (<i>Hibiscus abelmoschus</i>)										
15 Ramie (<i>Boehmeria nivea</i>)	1.52	20-30	25.5	91-99	5.0	3.7			167	1.53
16 Roselle (<i>Hibiscus sabdariffa</i>)										
17 Sanseveria (<i>Sanseveria</i> sp)			20	23.3		2.7				
18 Sisal (<i>Agave sisalana</i>)		45-90	10-30	40	5.0	2.0-2.5			127	0.317
19 Sunn (<i>Crotalaria juncea</i>)			31							
20 Urena (<i>Urena lobata</i>)										
21 Silk, boiled	1.25	Continuous	5-21	45.5	3.4	13-20	6.9-8.8	1.6	15	1.35
22 Wool, scoured ⁵	1.30	3.75-38	25	17.2	1.3	30-50	2.5-3.9	0.5	4	1.30

Fiber	Specific Heat	Moisture Regain ³ %	Cellulose g/100g ⁴	Holo-cellulose g/100g ⁴	α-Cellulose g/100g ⁴	Furfural Yield g/100g ⁴	Lignin g/100g ⁴	Fat and Wax g/100g ⁴	Water Extractables g/100g ⁴	Ash g/100g ⁴
1 Abaca (<i>Musa textilis</i>)	0.322		63-86			9	8.6	0.71	1.09	1.15
2 Banana (<i>M. paradisiaca sapientum</i>)				85	58	9.37	13.06			2.63
3 Cotton, Egyptian (<i>Gossypium peruvianum</i>)	0.319	7.0-8.5	90							
4 Cotton, Sea Island (<i>G. barbadense</i>)	0.319	7.0-8.5	90							
5 Cotton, Upland (<i>G. hirsutum</i>)	0.319	7.0-8.5	88-95					0.7	2.66	1.32
6 Coir (<i>Cocos nucifera</i>)			61				33			
7 Flax (<i>Linum usitatissimum</i>)	0.322	12	45-80	90	59	1.46	4.53	2.6	6.75	0.79
8 Green hemp (<i>Crotalaria tenuifolia</i>)				91	58	1.47	5.46			1.39
9 Hemp (<i>Cannabis sativa</i>)	0.323	12	59-85					0.62	3.82	0.90
10 Henequen (<i>Agave fourcroydes</i>)		4.6	48-88				5.4			1.1
11 Jute (<i>Chorchorus</i> sp)	0.324	13.8	51-88	83	61	6.64	11.78	0.82	1.14	0.50-1.56
12 Kenaf (<i>Hibiscus cannabinus</i>)		9.8	82		61-64		7.43-8.47			0.60-1.34
13 Mauritius hemp (<i>Fourcraea gigantea</i>)			81				18			2.0
14 Musk-dana (<i>Hibiscus abelmoschus</i>)				80	49	11.04	9.81			0.84
15 Ramie (<i>Boehmeria nivea</i>)		12	72-97	97	89	1.29	0.08		2.4	1.2
16 Roselle (<i>Hibiscus sabdariffa</i>)				84	54	9.61	6.88			0.61
17 Sanseveria (<i>Sanseveria</i> sp)			88	85	60	10.94	7.30		2.3-2.5	0.7-0.8
18 Sisal (<i>Agave sisalana</i>)		6.2	53-80	92	65	12.20	6.27			0.62
19 Sunn (<i>Crotalaria juncea</i>)		9.2	88	91	66	1.76	3.86	0.61	2.12	0.82
20 Urena (<i>Urena lobata</i>)			80	79	54	11.19	10.03			0.25
21 Silk, boiled	0.331	10.3-12.4								
22 Wool, scoured ⁵	0.326	14.7								

/1/ 1 Grex = 0.9 denier. 1 denier = wt in g per 9000 m fiber length. /2/ Values presented as dynes per sq cm x 10¹⁰. /3/ Moisture regain at 65% relative humidity, 21°C. /4/ Dry weight. /5/ Contains keratin, 98 g/100g.

32. THE PROTOPLASMIC SURFACE: PHYSICAL, CHEMICAL, AND ELECTRICAL CHARACTERISTICS

This table describes certain characteristics of the protoplasmic surface of some representative animal and plant cells. Values in parentheses are ranges and conform with estimate "d" of the 95% range (cf Introduction).

Part I: SURFACE TENSION

Organism	Cell	Dynes/cm
1 Sea urchin (<i>Arbacia punctulata</i>)	Egg, unfertilized	0.21
2 Sea urchin (<i>A. punctulata</i>)	Egg, fertilized	0.09 ²
3 Marine worm (<i>Chaetopterus pergamentaceus</i>)	Egg, unfertilized	1.31
4 Salamander (<i>Triturus viridescens</i>)	Egg, unfertilized	0.16 ³
5 Salamander (<i>T. viridescens</i>)	Egg, fertilized	0.10(0.06-0.17) ³
6 Marine mollusk (<i>Busyon canaliculatum</i>)	Egg, fertilized	0.34(0.13-0.66) ³
7 Clam (<i>Cumingia tellenoides</i>)	Egg, unfertilized	0.54 ¹
8 Mollusk (<i>Illyanassa obsoleta</i>)	Egg, fertilized	1.11
9 Newt (<i>Triturus pyrrhogaster</i>)	Erythrocyte	1.44
10 Frog (<i>Rana pipiens</i>)	Leukocyte	1.31
11 Rabbit (<i>Oryctolagus cuniculus</i>)	Leukocyte (macrophage)	2.11
12 Protozoa (<i>Amoeba dubia</i>)		(1-3) ¹
13 Slime mold (<i>Physarum polycephalum</i>)		(0.1-0.6) ¹

/1/ Centrifugal fragmentation technique. /2/ Kinetic (Poisseeuille's Law) technique. /3/ Sessile drop technique. /4/ Force to stretch cell with needle.

Part II: THICKNESS OF PLASMA MEMBRANE

Organism	Cell	Microns
1 Man (<i>Homo sapiens</i>)	Erythrocyte	(0.015-0.026) ¹
2 Man (<i>H. sapiens</i>)	Erythrocyte	0.52
3 Dog (<i>Canis familiaris</i>)	Erythrocyte	0.003 ³
4 Mouse (<i>Mus musculus</i>)	Mitochondria of cell of kidney tubule	0.016 ¹
5 Rabbit (<i>Oryctolagus cuniculus</i>)	Erythrocyte	0.012 ³
6 Rabbit (<i>O. cuniculus</i>)	Erythrocyte	(0.021-0.023) ⁴
7 Rabbit (<i>O. cuniculus</i>)	Leukocyte	0.003 ³
8 Protozoa (<i>Amoeba proteus</i>)		0.05 ¹
9 Bacteria (<i>Bacillus cereus</i>)		(0.21-0.35) ⁵
10 Yeast (<i>Saccharomyces</i> sp)		0.004 ³

/1/ Electron microscope. /2/ Diffraction method (wet membrane). /3/ Dielectric method. Assumed dielectric constant of 3. /4/ Leptoscopic method (dry membrane), pH 6.0. /5/ Microscopic stain technique.

Part III: ELECTROKINETIC PROPERTIES OF CELL MEMBRANES

Organism	Cell ¹	Zeta Potential mV	Electrophoretic Mobility μ/sec/V/cm	Organism	Cell ¹	Zeta Potential mV	Electrophoretic Mobility μ/sec/V/cm
1 Sea urchin (<i>Arbacia punctulata</i>)	Egg, unfertilized ²	30(26-36)	16(13-17)	14 Guinea pig (<i>Cavia porcellus</i>)	Leukocyte ⁶		1.20
2 Sea urchin (<i>A. punctulata</i>)	Egg, unfertilized ³	34(30-39)	18(15-20)	15 Horse (<i>Equus caballus</i>)	Erythrocyte ⁷	26.0	0.98(0.90-1.07)
3 Sea urchin (<i>Pseudocentrotus depressus</i>)	Egg, unfertilized ²	25		16 Horse (<i>E. caballus</i>)	Leukocyte ⁷	14.5	0.54(0.46-0.59)
4 Starfish (<i>Asterias forbesi</i>)	Egg, unfertilized ²	20		17 Horse (<i>E. caballus</i>)	Lymphocyte ⁷	17.0	0.60
5 Starfish (<i>A. forbesi</i>)	Egg, unfertilized ³	19		18 Horse (<i>E. caballus</i>)	Platelets ⁷	12.0	0.45(0.40-0.51)
6 Marine clam (<i>Cumingia tellenoides</i>)	Egg, unfertilized ²	29		19 Monkey (<i>Macaca mulatta</i>)	Erythrocyte	17.0	1.33
7 Marine clam (<i>C. tellenoides</i>)	Egg, unfertilized ³	34(31-37)		20 Mouse (<i>Mus musculus</i>)	Erythrocyte	17.9	1.4
8 Man (<i>Homo sapiens</i>)	Erythrocyte	16.8	1.31 ⁴	21 Opossum (<i>Didelphis azarae</i>)	Erythrocyte	13.7	1.07
9 Man (<i>H. sapiens</i>)	Leukocyte ⁵		0.38(0.33-0.44)	22 Rabbit (<i>Oryctolagus</i> sp)	Erythrocyte	7.0	1.03(1.01-1.08) ⁴
10 Man (<i>H. sapiens</i>)	Lymphocyte ⁵		0.51(0.47-0.56)	23 Rat (<i>Rattus rattus</i>)	Erythrocyte	18.6	1.45
11 Cat (<i>Felis catus</i>)	Erythrocyte	17.8	1.39	24 Sloth (<i>Bradypus griseus</i>)	Erythrocyte	12.4	0.97
12 Dog (<i>Canis familiaris</i>)	Erythrocyte	21.1	1.68	25 Swine (<i>Sus scrofa</i>)	Erythrocyte	12.5	0.98
13 Guinea pig (<i>Cavia porcellus</i>)	Erythrocyte	14.2	1.11	26 Bacteria (β-hemolytic streptococci)	Cell		1.06
				27 Bacteria (<i>Escherichia coli</i>)	Cell	(34-42) ⁸	0.64 ⁹

/1/ All blood cells suspended in M/15 phosphate buffer solution of pH 7.4, unless otherwise indicated. /2/ Jelly removed from cell. /3/ Jelly not removed from cell. /4/ Suspended in an isotonic phosphate-buffer-glucose solution, pH 7.2. /5/ Suspended in physiological salt solution, pH 7.4. /6/ Suspended in M/15 phosphate buffer, pH 7.0. /7/ Suspended in plasma or serum. /8/ Suspended in N/100 lactate buffer, pH 4.7. /9/ Suspended in M/15 phosphate buffer solution, pH 6.9.

Part IV: PERMEABILITY OF CELL SURFACES TO WATER

Values are cu μ per sq cm surface area per minute per atmosphere difference in osmotic pressure x 10 ⁶ , unless otherwise indicated. Experimental temperature, approximately 20° C.			
Animal	Value		
1 Protozoa		8 Sand dollar (<i>Dendraster</i> sp)	(10-40)
2 <i>Amoeba proteus</i>	0.21 ¹	9 Marine clam (<i>Cumingia tellenoides</i>)	41(40-42)
3 <i>Gregarina</i> sp	20	10 Marine worm (<i>Chaetopterus pergamentaceus</i>)	(46-47)
4 <i>Zoothamnium</i> sp	(12-25)	11 Marine worm (<i>Urechis caupo</i>)	27
Eggs ²		12 Erythrocytes (except where indicated)	
5 Sea urchin (<i>Arbacia punctulata</i>)	10(9-13)	13 Man (<i>Homo sapiens</i>)	360
6 Sea urchin (<i>A. punctulata</i>)	14 ³	14 Man (<i>H. sapiens</i>)	135 ⁴
7 Sea urchin (<i>Pseudocentrotus depressus</i>)	21(18-24)	15 Cattle (<i>Bos taurus</i>)	250
8 Starfish (<i>Patiria miniata</i>)	(10-40)	16 Rabbit (<i>Oryctolagus cuniculus</i>)	(35-1164) ⁵
		17 Rabbit (<i>O. cuniculus</i>)	
		18 Skeletal muscle	
		19 Frog (<i>Rana pipiens</i>)	(118-666) ⁵
		Plant	Value
		20 Algae (<i>Halicystis osterhoutii</i>)	230(220-250)
		21 Algae (<i>Nitella flexilis</i>)	4632 ⁵
		22 Algae (<i>Spirogyra</i> sp)	3900 ⁵
		23 Fern, water (<i>Salvinia auriculata</i>)	55
		24 Onion (<i>Allium cepa</i>)	30

/1/ Unit is μ/sec. /2/ Unfertilized. /3/ Outward flow. /4/ Leukocytes. /5/ Unit is mol/sq cm surface area/min/g mol difference in concentration x 10⁻⁸.

Part V: PERMEABILITY OF CELL SURFACES TO IONS

[illegible]

TABLE VI. PERMEABILITY OF CELL SURFACES TO NON-ELECTROLYTES

Values are in mol per sq cm surface area per minute per g mol difference in concentration $\times 10^{-6}$, unless otherwise indicated. Temperature range, 20–25°C.

ETHYLENE GLYCOL		Value	PROPYLENE GLYCOL		Value	ERYTHRITOL		Value
Animal			Animal			Animal		
1	Protozoa Gregarina sp Eggs ¹	40.2	21	Protozoa (Gregarina sp) Eggs ¹	79.2	44	Erythrocytes Cattle (Bos taurus) Hedgehog (Marmota monax)	<0.003 31.7
2	Sea urchin (Arbacia punctulata)	36(29-56)	22	Sea urchin (Arbacia punctulata)	77	Plant		
3	Starfish (Asterias sp)	102(50-182)	23	Erythrocytes Cattle (Bos taurus)	19.8	46	Algae (Cerarium diaphanum)	0.1
4	Marine worm (Chaetopterus pergamentaceus)	143(140-153)	24	Worm (Phascolosoma gouldi)	11.7	47	Algae (Chara ceratophylla)	0.08
5	Marine clam (Cumingia tellenoides)	156(151-163)	Plant			48	Algae (Melosira sp)	0.8
Erythrocytes			25	Algae (Chara ceratophylla)	145	49	Algae (Pylaiella littoralis)	0.007
6	Cattle (Bos taurus)	9.6	GLYCEROL			50	Algae (Spirogyra sp)	0.02
7	Hedgehog (Erinaceus europaeus)	246	Animal			51	Bacteria (Bacterium paracoli)	0.3
8	Worm (Phascolosoma gouldi)	7.3	26	Protozoa (Gregarina sp) Eggs ¹	1.1	52	Bacteria (Beggiatoa mirabilis)	50.3
Plant			27	Sea urchin (Arbacia punctulata)	5	53	Moss (Plagiothecium denticulatum)	0.004
9	Algae (Cerarium diaphanum)	49.8	28	Marine worm (Chaetopterus pergamentaceus)	62(58-69)	54	Oyster plant (Rhoeo discolor)	0.03
10	Algae (Chara ceratophylla)	71.6	Erythrocytes			55	Turmeric (Curcuma rubricaulis)	0.02
11	Algae (Melosira sp)	22.5	29	Man (Homo sapiens)	9	SACCHAROSE		
12	Algae (Pylaiella littoralis)	5.8	30	Cattle (Bos taurus)	0.11	Plant		
13	Algae (Spirogyra sp)	6.6	31	Hedgehog (Erinaceus europaeus)	163	56	Algae (Chara ceratophylla)	0.05
14	Bacteria (Beggiatoa mirabilis)	83.4	32	Worm (Phascolosoma gouldi)	<0.004	57	Algae (Melosira sp)	0.4
15	Moss (Plagiothecium denticulatum)	2	Plant			58	Bacteria (Beggiatoa mirabilis)	8.1
16	Oyster plant (Rhoeo discolor)	10.4	33	Algae (Cerarium diaphanum)	1.3	59	Moss (Plagiothecium denticulatum)	0.0005
17	Turmeric (Curcuma rubricaulis)	6.6	34	Algae (Chara ceratophylla)	1.2	60	Turmeric (Curcuma rubricaulis)	0.0005
DIETHYLENE GLYCOL			ACETAMIDE			Value		
Animal			Animal			Animal		
18	Eggs ¹ Sea urchin (Arbacia punctulata)	26	35	Algae (Melosira sp)	2	61	Eggs ¹ Sea urchin (Arbacia punctulata)	(55-60)
Erythrocytes			36	Algae (Pylaiella littoralis)	0.1	Erythrocytes		
19	Cattle (Bos taurus)	4.5	37	Algae (Spirogyra sp)	0.2	62	Cattle (Bos taurus)	283
20	Worm (Phascolosoma gouldi)	3.7	38	Bacteria (Bacterium paracoli)	3.3	63	Worm (Phascolosoma gouldi)	15.8
			39	Bacteria (Beggiatoa mirabilis)	63.6	Plant		
			40	Moss (Plagiothecium denticulatum)	0.02	64	Algae (Chara ceratophylla)	90
			41	Maianthemum (Maianthemum sp)	9.8 ²			
			42	Oyster plant (Rhoeo discolor)	0.7			
			43	Turmeric (Curcuma rubricaulis)	0.1			

/1/ Unfertilized. /2/ Unit is mol/min $\times 10^{-4}$

Part VI: PERMEABILITY OF CELL SURFACES TO NON-ELECTROLYTES (Concluded)

Values are in mol per sq cm surface area per minute per g mol difference in concentration $\times 10^{-8}$, unless otherwise indicated. Temperature range, 20-25°C.

ACETAMIDE (concluded)		Value	UREA		Value
Plant (concluded)			Animal		
65	Algae (Melosira sp)	28.2	92	Erythrocytes	
66	Algae (Pylaiella littoralis)	16.8	93	Man (Homo sapiens)	1166
67	Moss (Plagiothecium denticulatum)	4	94	Cattle (Bos taurus)	1080
68	Turmeric (Curcuma rubricaulis)	4.8	95	Hedgehog (Erinaceus europaeus)	1666
PROPIONAMIDE		Value	Worm (Phascolosoma gouldi) <td>1.6</td>		1.6
Animal			Plant		
69	Eggs ¹		96	Algae (Ceranium diaphanum)	5
	Sea urchin (Arbacia punctulata)	(134-150)	97	Algae (Chara ceratophylla)	6.7
	Erythrocytes		98	Algae (Melosira sp)	2.5
70	Cattle (Bos taurus)	114	99	Algae (Pylaiella littoralis)	0.5
71	Worm (Phascolosoma gouldi)	62.3	100	Algae (Spirogyra sp)	1.1
Plant			101	Bacteria (Bacterium paracoli)	5
72	Algae (Ceranium diaphanum)	168	102	Bacteria (Beggiatoa mirabilis)	70.2
73	Algae (Chara ceratophylla)	216	103	Moss (Plagiothecium denticulatum)	0.2
74	Algae (Melosira sp)	180	104	Maianthemum (Maianthemum sp)	(23.4-33.3) ²
75	Algae (Pylaiella littoralis)	84	105	Oyster plant (Rhoeo discolor)	0.2
76	Algae (Spirogyra sp)	27	106	Turmeric (Curcuma rubricaulis)	0.09
77	Moss (Plagiothecium denticulatum)	12	METHYL UREA		Value
78	Oyster plant (Rhoeo discolor)	9.6	Plant		
79	Turmeric (Curcuma rubricaulis)	13.2	107	Algae (Ceranium diaphanum)	5.8
MALONAMIDE		Value	108	Algae (Chara ceratophylla)	11.4
Animal			109	Algae (Melosira sp)	7.2
80	Protozoa (Gregarina sp)	15	110	Algae (Pylaiella littoralis)	1.9
Plant			111	Algae (Spirogyra sp)	1.7
81	Algae (Ceranium diaphanum)	1.5	112	Moss (Plagiothecium denticulatum)	0.7
82	Algae (Chara ceratophylla)	0.2	113	Maianthemum (Maianthemum sp)	75 ²
83	Algae (Melosira sp)	1.1	114	Oyster plant (Rhoeo discolor)	0.5
84	Algae (Pylaiella littoralis)	0.1	115	Turmeric (Curcuma rubricaulis)	0.5
85	Algae (Spirogyra sp)	0.1	THIOUREA		Value
86	Bacteria (Bacterium paracoli)	1.7	Animal		
87	Bacteria (Beggiatoa mirabilis)	94.8		Erythrocytes	
88	Moss (Plagiothecium denticulatum)	0.05	116	Cattle (Bos taurus)	1.2
89	Maianthemum (Maianthemum sp)	5.5 ²	117	Hedgehog (Erinaceus europaeus)	138
90	Oyster plant (Rhoeo discolor)	0.01	118	Worm (Phascolosoma gouldi)	2
91	Turmeric (Curcuma rubricaulis)	0.02	Plant		
			119	Algae (Chara ceratophylla)	12.8

120	Maianthemum (Maianthemum sp)	90 ²
121	Oyster plant (Rhoeo discolor)	21 ²
MANNITOL		Value
Animal		
	Erythrocytes	
122	Man (Homo sapiens)	<0.33
123	Cattle (Bos taurus) ³	<0.003
124	Hedgehog (Erinaceus europaeus) ⁴	2
Plant		
125	Algae (Chara ceratophylla)	<0.05
BUTYRAMIDE		Value
Animal		
	Eggs ¹	
126	Sea urchin (Arbacia punctulata)	(338-394)
	Erythrocytes	
127	Cattle (Bos taurus)	163
128	Worm (Phascolosoma gouldi) ⁵	410
MONACETIN		Value
Animal		
	Erythrocytes	
129	Cattle (Bos taurus)	6.8
130	Worm (Phascolosoma gouldi)	0.6
Plant		
131	Algae (Chara ceratophylla)	26.6
DIACETIN		Value
Animal		
	Erythrocytes	
132	Cattle (Bos taurus)	62.5
133	Worm (Phascolosoma gouldi)	4.5
Plant		
134	Algae (Chara ceratophylla)	133
TRIMETHYLENE GLYCOL		Value
Animal		
	Eggs ²	
135	Sea urchin (Arbacia punctulata)	43
	Erythrocytes	
136	Cattle (Bos taurus)	6
137	Worm (Phascolosoma gouldi)	7.3

/1/ Unfertilized. /2/ Unit is mol/min $\times 10^{-4}$. /3/ Triethylene glycol = 2; xylose = <0.003; formamide = 293; propyl alcohol=636. /4/ Xylose = 0.66. /5/ Formamide = 9.8; tetraethylene glycol = 0.4; triethylene glycol = 1.2

Part VII: COMPOSITION OF ERYTHROCYTE STROMA

Species		Protein	Lipid	Phospholipid	Cholesterol	Neutral Fat	Species		Glycine	Leucine	Tyrosine	Tryptophan	Total Nitrogen	Amino Nitrogen					
		Per cent of Stroma							Per cent Anhydrous Ash-free Stroma Protein										
1	Man (Homo sapiens)	49.5	11.2	7.3	2.6	1.8	10	Man (Homo sapiens)	3.6	11.2			15.9	11.6					
2	Cattle (Bos taurus)	57	25.6	15.9	7.5	2.0	11	Cattle (Bos taurus)	3.7	10.1	3.4	1.4	13.7	10.4					
3	Chicken (Gallus domesticus)	91	3.9	2.5	1.1	0.2	12	Sheep (Ovis aries)	3.7	11.4			15.3	12.0					
4	Horse (Equus caballus)	53	20.4	12.7	7.4	0.3	Species								Lipid		Cephalin	Lecithin	Cholesterol
5	Sheep (Ovis aries)	68.4	23.9	14.7	4.9	4.3									mg per sq μ Stroma Surface Area $\times 10^{-12}$				
Species		Histidine	Arginine	Lysine	Tyrosine	Tryptophan	Cysteine	Methionine	13	Man (Homo sapiens)	4.2								
Molecular Ratio in Stroma							14	Cat (Felis catus)	4.4										
6	Man (Homo sapiens)	7	15	14.5	8	3	2	3.5	15	Cattle (Bos taurus)	3.9	2.3	0.2	0.6					
7	Cattle (Bos taurus)	6.5	15	12	8	3	2	3	16	Dog (Canis familiaris)	4.9								
8	Horse (Equus caballus)	7	14.5	13.5	8	3	2	4	17	Monkey (Macaca mulatta)	4.7	2.0	1.3	1.3					
9	Sheep (Ovis aries)	8	14	11.5	7	2.5	2	4	18	Rabbit (Oryctolagus sp)	3.9	1.5	0.4	1.2					
									19	Rat (Rattus rattus)	4.3	2.4	0.4	0.8					
									20	Sheep (Ovis aries)	5.6								

33. VITAMINS AND PROVITAMINS: PHYSICAL AND CHEMICAL CHARACTERISTICS

Vitamin or Provitamin	Common Alternate Designations	Chemical Name	Molecular Formula	Units in Which Expressed	Physical State ¹	Melting or Boiling Point ¹ °C	Stability ¹	Solubility ^{1,2} g/100 ml	Specific Rotation ¹ [α] _D ²⁵	Absorption Maxima ¹
Vitamins										
1 Vitamin A ₁	Axerophthol; anti-xerophthalmia factor.	3, 7-Dimethyl-9-(2, 6, 6-trimethyl-1-cyclohexen-1-yl)-2, 4, 6, 8-nonatetraen-1-ol.	C ₂₀ H ₃₀ O	0.30 μg vitamin A alcohol, or 0.344 vitamin A acetate = one I.U. = one U.S.P. unit.	Pale yellow crystals.	62-64. Distills at 120-125 at 5x10 ⁻³ mm.	Inactivated by ultra-violet. Sensitive to air-oxidation.	s. most org. solv., fats, oils; i.w.	None.	325.5 in isopropanol.
2 Vitamin A ₂			C ₂₀ H ₂₈ O		Yellow prisms.					351, 328
3 Vitamin A, neo-		5-cis-Vitamin A.	C ₂₀ H ₃₀ O		Yellow needles.	59-60				
4 Ascorbic acid	Vitamin C; anti-scorbutic factor.	L-Threo-2, 3, 4, 5-6-pentahydroxy-2-hexeno-γ-lactone.	C ₆ H ₈ O ₆	0.05 mg = one I.U. or one U.S.P. unit.	Crystals, plates or needles; monoclinic, colorless.	190-192 with some decomposition.	Stable to air when dry. Impure preparations and natural products oxidized by air and light.	33 w. 3.5 al. 2 abs. al. 1 glyc.	+20.5-21.5 ²⁵ in w. +48 ²³ in me. al.	243.5 in metaphosphoric acid.
5 Biotin	Vitamin H; coenzyme R; factor S, W, X; bios II G; anti-egg white injury factor.	cis-Hexahydro-2-oxo-1H-thieno [3, 4] imidazole-4-valeric acid.	C ₁₀ H ₁₆ N ₂ O ₃ S	Gravimetric.	Fine, long needles or white crystalline powder.	232-233 (some decomposition).	Stable to air, temp. Moderately acid and neutral sol. stable several months; alk. sol. less stable.	0.022 w ²⁵ 0.080 al. ²⁵ More s.h.w. or dil. alk.	+91 ²¹ in 0.1 N NaOH.	
6 Choline		(β-Hydroxyethyl)trimethylammonium hydroxide.	C ₅ H ₁₅ NO ₂	Gravimetric.	Colorless, viscous, hygroscopic, alk. liquid.		Dil. aq. sol. stable to boiling; dec. hot alkali.	v.s.w., al.; i. eth.		
7 Cobalamin	Cyanocobalamin (vitamin B ₁₂); hydroxycobalamin (vitamin B _{12a} , B _{12b}).	Not fully determined.	C ₆₁ -64H ₈₆ -92 N ₁₄ O ₁₃ PCo	Gravimetric.	Hyg. dark red needles. Birefringent.	Darkens 210-220. Not melted 300.	Heat stable in aq. sol. Inactivated slowly by weak acid, alkali.	1.25 w.; s.al.; i.chl., acet., eth.	-59 ²³ ± 9 in 656 dil. aq. sol.	548-550, 361, 278 in 0.1 N NaOH.
8 Vitamin D ₂	Calciferol; activated ergosterol; anti-rachitic factor.	9, 10-Secoergosta-5, 7, 10(19), 22-tetraen-3-ol.	C ₂₈ H ₄₄ O	Crystals = 40 million I.U. or U.S.P. units per gram.	Prisms from acetone.	115-118 Sublimes in very high vacuum without decomposition.	Crystals stable 9 mo. in amber-evacuated ampuls at 4°C. Propylene glycol sol. stable in air for long periods of time.	6.95 acet. ⁷ ; s. most org. solv.; sl. s. vegetable oils; i. w.	+103 ²⁰ in al. +82.6 in acet. +91.2 in eth. +52 in chl.	264.5±0.5 in ethanol or hexane.
9 Vitamin D ₃	Activated 7-dehydro-cholesterol.	22, 23-Dihydro-24-demethylcalciferol.	C ₂₇ H ₄₄ O	Crystals = 40 million I.C.U. ⁴ or I.U. per gram.		82-83		s. most fat solv.; i.w.	+83.3 ²⁰ in acet.	
10 Vitamin E	α-Tocopherol, anti-sterility factor.	5, 7, 8-Trimethyltolcol.	C ₂₉ H ₅₀ O ₂	One mg α-tocopherol acetate = one I.U.	Slightly viscous pale-yellow oil.	Boils 200-220 at 0.1 mm.	Very stable to heat, a. Slowly oxidized by atmospheric O ₂ , rapidly by ferric and silver salts.	v.s. oils, fats, acet., chl., al., eth.; i.w.	+0.32 ²⁵ 546.1 in al. -3.0 in bz.	292 in ethanol.
	β-Tocopherol ⁵ .	5, 8-Dimethyltolcol.	C ₂₈ H ₄₈ O ₂		Yellow oil.		Same as α-	Same as α-	+2.9 ²⁵ 546.1 in al.	295
	γ-Tocopherol ⁵ .	7, 8-Dimethyltolcol.	C ₂₈ H ₄₈ O ₂		Crystals.		Same as α-	Same as α-	+2.2 ²⁵ 546.1 in al.	295
	δ-Tocopherol ⁵ .	8-Methyltolcol.	C ₂₇ H ₄₆ O ₂		Yellow oil.		Same as α-	Same as α-	+3.4 ²⁵ 546.1 in al.	298
11 Inositol	meso-Inositol; i-inositol; bios I.	Hexahydroxycyclohexane.	C ₆ H ₁₂ O ₆	Gravimetric.	Efflorescent crystals (dihydrate).	218 (dihydrate) 250-253 anhyd.	Becomes anhydrous at 100°. Decomposes at 250°.	17.5 w. i.abs.al., eth.	Inactive.	
12 Vitamin K ₁	Antihemorrhagic vitamin;	2-Methyl-3-phytyl-1, 4-naphthoquinone.	C ₃₁ H ₄₆ O ₂	Gravimetric in terms of menadione.	Yellow, viscous oil.	-20. Dec. above 100-120.	Stable to air, moisture. Dec. sunlight.	i.w.; sl.s.me. al.; s.al., chl., bz., acet., eth.	-0.4 ²⁰ (57.5% in bz.)	239, 243, 249, 260, 270, 325 in hexane.
13 Vitamin K ₂	vitamin K ⁶ .	2-Methyl-3-difarnesyl-1, 4-naphthoquinone.	C ₄₁ H ₅₆ O ₂		Yellow crystals.	53.5-54.5	Stable dil.a.; labile alk. hydroxides.			
14 Niacin	Nicotinic acid; P.P. factor.	Pyridine-3-carboxylic acid.	C ₆ H ₅ NO ₂	Gravimetric.	Colorless needles.	236.5	Stable in air, and to light and pH. Non-hyg.	1.67 w ²⁵ 0.73 al. ²⁵ ; i. eth.	Inactive.	213, 263, 212, 261 in hexane.

15	Niacinamide	Nicotinic acid amide.	Pyridine-3-carboxamide.	C ₆ H ₆ N ₂ O	Gravimetric	White cryst. powder.	129-131		100 w.; 66.6 al.; sl. s. eth.	Inactive.	
16	Pantothenic acid	Chick anti-dermatitis factor; factor II.	D(+)-N-(α, γ-Dihydroxy-β, β-dimethylbutyryl)-β'-alanine.	C ₉ H ₁₇ NO ₅	One "chick unit" = 0.14 μg D-pantothenic acid.	Colorless, viscous oil.	Unstable. Ca salt dec. 195-196.	Very hyg. Labile to a., alk., heat. Ca salt stable to air and light.	v.s.w., glac. acet. a.; sl. s. eth.; i. bz., chl.	+37.5 ²⁵ Ca salt: +28.2 ²⁵	
17	Para-amino-benzoic acid	PABA	p-Aminobenzoic acid.	C ₇ H ₇ NO ₂	Gravimetric.	Mono-clinic prisms from dil. al.	187.0-187.5	Incompatible with ferric salts and oxidizing agents.	0.5 w. ²⁵ ; v.s. al., eth., glac. acet. a.; sl. s. bz.	Inactive.	264 in alk.; 225, 270 in a.
18	Pteroyl-glutamic acid	PGA; folic acid; folacin, vitamin M; L. casei factor; vitamin B ₉ .	N-[4- {[(2-Amino-4-hydroxy-6-pteridyl)-methyl]-amino}-benzoyl]-glutamic acid.	C ₁₉ H ₁₉ N ₇ O ₆		Yellowish-orange crystals.	Darkens and chars from about 250°.	Very labile to heat in a. media. Sun-light causes deterioration.	sl. s.w., me. al.; i. acet., chl., eth., bz.; s. acet. a.		257, 282, 365 in 0.1 N NaOH.
19	Pyridoxine ⁷	Vitamin B ₆ -HCl; anti-acrodynia factor; adermine.	5-Hydroxy-6-methyl-3, 4-pyridine dimethanol hydrochloride.	C ₈ H ₁₁ NO ₃ ·HCl	Gravimetric.	White, odorless powder.	205-212 dec. Sublimes: free base 160.	Fairly stable to light and air. Acid sol. stable; may be heated 120° for 30 minutes.	22 w.; 1. l eth. al.; sl. s. acet.; i. eth.	Inactive.	291; 220, 254, 325; 245, 309.5 ⁸
20	Riboflavin	Vitamin B ₂ ; vitamin G; lactoflavin; ovoflavin; hepatoflavin.	6, 7-Dimethyl-9-(D-1'-ribityl)-isoalloxazine.	C ₁₇ H ₂₀ N ₄ O ₆	Gravimetric.	Yellow to orange-yellow polymorphic crystals.	277-291 with decomposition.	When dry, stable to diffused light. Very labile in alk. sol. especially in light. Stable to mineral acids in dark.	0.019 ⁴⁰ w.; 0.045 ^{27.5} al.; i. eth., acet., chl., bz.	-112 to -122 in dil. alcoholic NaOH (50 mg in 2 ml).	223, 267, 375, 444 in 0.1 N HCl.
21	Thiamine	Vitamin B ₁ ; aneurin; anti-neuritic factor.	3-(4-Amino-2-methylpyrimidyl-5-methyl)-4-methyl-5-β-hydroxyethylthiazolium chloride hydrochloride ⁹ .	C ₁₂ H ₁₇ N ₄ OSCl·HCl	1 gram contains 330,000 I.U. pure thiamine-HCl.	Monoclinic plates in rosette clusters, or white powder.	246-250 dec.	When dry, stable at 100°. Very hyg. absorbing nearly one mole H ₂ O in air forming a hydrate.	100 w.; 1 al.; 0.3 abs. al.; 5 gly.; i. bz., eth., chl., hexane.	Inactive.	246; 263 in 0.1 N HCl.
Provitamins											
22	β-Carotene ¹⁰	Provitamin A.		C ₄₀ H ₅₆	0.0006 mg = one I.U.	Red crystals.	180 corr.	Sensitive to O ₂ , autooxidation in light; stable to heat.	l.w.; sl. s. al., eth.; s. bz., pet. eth., CS ₂		520, 485 450 in CS ₂ .
23	Ergosterol	Provitamin D ₂ .	Δ ⁵ , 7, 22-Ergostatrien-3β-ol.	C ₂₈ H ₄₄ O		Small white plates from al.	168	Destroyed by UV; dec. oxid. agents.	v.s. most fat solv.; i. w.	-130 in chl.	280 in eth.
24	7-Dehydro-cholesterol	Provitamin D ₃ .	Δ ⁵ , 7-Cholestadien-3β-ol.	C ₂₇ H ₄₄ O		Crystals.	150		v.s. most fat solv.; i. w.	-113 in chl.	280 in eth.
25	22-Dihydro-ergosterol	Provitamin D ₄ .		C ₂₈ H ₄₆ O		Crystals.	152-153		v.s. most fat solv.; i. w.	-109 in chl.	
26	7-Dehydro-sitosterol	Provitamin D ₅ .		C ₂₉ H ₄₉ O		Crystals.	144-145		v.s. most fat solv.; i. w.	-116 in chl.	260
27	7-Dehydro-stigmasterol	Provitamin D.		C ₂₉ H ₄₆ O		Crystals.	154		v.s. most fat solv.; i. w.	-113.1 in bz.	
28	Epi-7-dehydro-cholesterol	Provitamin D.		C ₂₇ H ₄₄ O		Crystals.	124-126		v.s. most fat solv.; i. w.	-70.5 in chl.	
29	Kitol	Dimer of vitamin A.		C ₄₀ H ₆₀ O ₂		Prisms from al.	88-90		v.s. most fat solv.; i. w.	-1.35 in chl.	290
30	Lumisterol	Provitamin D ¹¹ .		C ₂₈ H ₄₄ O			118		v.s. most fat solv.; i. w.	+192 in acet.	
31	Panthenol	Provitamin(?) of pantothenic acid.	D(+)-3-(α, γ-dihydroxy-β-β-dimethyl butyryl)aminopropanol.	C ₉ H ₁₉ NO ₄	Gravimetric.	Colorless, viscous oil.	Racemizes at boiling point.	Labile to a., alk.	v.s.w., al.; sl. s. eth.	+29.7 ²⁰ (3% aq.)	
32	Tachysterol	Provitamin ¹¹ .		C ₂₈ H ₄₄ O					v.s. most fat solv.; i. w.	-70 in bz.	280

/1/ Abbreviations: a.=acid; abs.=absolute; acet.=acetone; glac. acet. a. =glacial acetic acid; al.=alcohol (95% ethyl); alk.=alkali; anh.=anhydrous; aq.=aqueous; bz.=benzene; chl.=chloroform; corr.=corrected; cryst.=crystals, crystalline; dec.=decomposes; dil.=dilute; eth.=ether; glyc.=glycerol; h.=hot; hyg.=hygroscopic; i.=insoluble; me.=methyl; org.=organic; oxid.=oxidizing; pet.=petroleum; s.=soluble; sl.=slightly; sol.=solution; solv.=solvents; UV=ultraviolet; v.=very; w.=water. /2/ Superscripts indicate temperature of solvent. /3/ Superscripts indicate temperature of measurement. /4/ International Chick Unit. /5/ Much less active than α-tocopherol. /6/ Synthetic vitamin K, menadione (2-methyl-1,4-naphthoquinone), has similar activity as natural K. /7/ The vitamin B₆ group also includes pyridoxal and pyridoxamine, with different properties and biological activity. /8/ First value in 0.1 N HCl, next three in phosphate buffer at pH 7, and last two in 0.1 N NaOH. /9/ The mononitrate is a less hygroscopic form. /10/ Other carotenoids having vitamin A activity are α-carotene, γ-carotene, neo-β-carotene and cryptoxanthin. /11/ Intermediates between provitamin and vitamin.

34. MILK, CHEMICAL COMPOSITION: MAN, COW, GOAT

Ranges are given in parentheses, and represent estimate "c" of the 95% range (cf Introduction).

Constituent per 100 ml Whole Milk	Man			Cow	Goat
	Colostrum ¹	Transitional Milk ²	Mature Milk	Mature Milk	
1 Water, g	87(83-90)	86(84-90)	88(83-90)	87(80-92)	87(81-90)
2 Calories, utilizable ³	57	64	65	65	68
3 Total solids, g	12.8(10-17)	13.6(10-16)	12.4(10-17)	12.7(8-20)	13.4(10-19)
4 Ash, g	0.33(0.2-0.7)	0.24(0.1-0.4)	0.21(0.1-0.5)	0.72(0.3-1.2)	0.77(0.4-1.1)
5 Protein, g	2.7(1-21)	1.6(1-3)	1.2(1-6)	3.3(2-6)	3.3(2-5)
6 Amino acids, total ⁴ , g	1.20(0.7-4.0)	0.94(0.4-1.3)	1.28(0.9-1.6)	3.3(2.7-4.1)	2.5(1.7-3.9)
7 Casein, g	1.2(0.3-5.2)	0.7(0.4-1.8)	0.4(0.04-0.7)	2.8(1.4-6.3)	0.4(0.4-0.6)
8 Lactalbumin, g		0.8	0.3(0.1-0.6)	0.4(0.2-0.6)	0.3
9 Lactoglobulin, g	3.5(0.4-13)	0.5(0.2-1.4)	0.2	0.2(0.1-0.4)	1.1(0.8-2.0)
10 Whey protein, g	1.7		0.6(<0.3-1.1)	0.6(0.2-1.4)	4.7(3.3-6.4)
11 Carbohydrate, g	5.3(1.1-7.9)	6.6(4.8-8.4)	7.0(4.2-9.2)	4.8(2.1-6.1)	4.1(1.2-8.4)
12 Fat, g	2.9(0.7-12.7)	3.6(0.4-9.6)	3.8(0.5-9.0)	3.7(0.9-9.8)	168
13 "Essential" fatty acids ⁵ , mg	246		346	96	
14 Vitamin A, estimated total ⁶ , mg	0.1(0.02-0.47)	0.1(0.06-0.2)	0.06(0.01-0.25)	0.04(0.015-0.95)	1.4(Trace-3.2)
15 Ascorbic acid, mg	4.4(0.4-10.4)	5.4(2.7-9.0)	4.3(0-11.2)	1.6(0.2-3.1)	6.3(4.7-8.3)
16 Biotin, µg	0.1(Trace-0.3)	0.4(Trace-1.8)	0.4(Trace-4.2)	3.5(0.2-11.0)	13(4-28)
17 Choline, mg			9(5-14)	0.56(0.07-1.15)	0.02(0-0.14)
18 Cobalamin ⁷ , µg	0.04(0.01-0.15)	0.04(0-0.07)	Trace	0.06(0.01-0.1)	
19 Vitamin D, calc. as calciferol ⁸ , µg			0.01(0-0.25)	0.1	0.03(0-0.16)
20 Vitamin E, mg	1.3(0.1-4)	1.3(0.5-3)	0.6(0.1-1)	0.2(0.1-5)	21(14-26)
21 Folic acid group ⁹ , µg	0.05(0.01-0.15)	0.02(0.015-0.025)	0.2(0.1-0.36)	13(3-39)	8(0-33)
22 Inositol, mg			39(19-56)	85(19-150)	273(200-320)
23 Vitamin K, calc. as K ₁ ¹⁰ , µg			2(0-17)	350(155-568)	289(130-338)
24 Niacin ¹¹ , µg	75(<10-145)	175(60-360)	172(66-690)	(?)	(?)
25 Pantothenic acid, µg	183(29-302)	288(135-412)	196(80-584)	48(3-95)	7(4-13)
26 Para-aminobenzoic acid	(?)	(?)	(?)	157(20-342)	114(76-650)
27 Pyridoxine group ¹² , µg			11(2-22)	42(27-90)	48(32-68)
28 Riboflavin, µg	29.6(12-50)	33.2(27-49)	42.6(13-100)		
29 Thiamine, µg	15(0.5-82)	6(0-26)	16(<1-43)		
30 Calcium, mg	31(13-66)	34(18-63)	33(15-61)	125(56-381)	130(103-176)
31 Chlorine, mg	91(20-233)	54(17-116)	43(9-355)	103(70-290)	159(56-260)
32 Cobalt, µg				0.06	
33 Copper, mg	0.05(0.02-0.6)	0.05(0.04-0.07)	0.04(0.01-0.07)	0.03(0.003-0.40)	0.04(0.02-0.05) ¹³
34 Fluorine, µg				16(7-28)	
35 Iodine, µg	12(4.5-45)	2	7(4-9)	21(0.4-187)	
36 Iron, mg	0.09(0.02->0.13)	0.04(0.02-0.05)	0.15(0.02-0.45)	0.10(0.01-1.0)	0.05(0.01-0.07)
37 Magnesium, mg	4(1-8)	4(2-5)	4(2-6)	12(7-22)	16(10-24)
38 Manganese, µg	Trace		0.7	2(<1-4)	8(7-9)
39 Phosphorus, µg	14(6-25)	17(10-32)	15(7-35)	96(56-129)	106(84-161)
40 Potassium, mg	74(66-87)	64(53-77)	55(27-81)	138(38-287)	181(106-242)
41 Silicon				Trace	
42 Sodium, mg	48(26-136)	29(19-54)	15(2-44)	58(31-214)	41(19-60)
43 Sulfur, mg	22(20-26)	20(15-23)	14(5-30)	30(24-44)	16(2-29)
44 Zinc, mg	0.62(0.07-0.98)	0.77(0.04->1.15)	0.53(0.02->1.38)	0.38(0.17-0.66)	Trace

/1/ 1st-5th day of lactation. /2/ 6th-10th day of lactation. /3/ Kilocalories, calculated on basis of "physiological fuel values" of 8.80 calories per gram of fat; 3.85 calories per gram of carbohydrate (lactose); and 4.25 calories per gram of protein. /4/ Represents only the total of values that are available. /5/ Arachidonic, octadecadienoic acid. /6/ Milligrams of carotenoids x 0.75 ÷ (0.6 x 4.3), plus mg preformed vitamin A = estimated total vitamin A. /7/ Vitamin B₁₂, cyanocobalamin. /8/ 0.025 µg calciferol = one I. U. /9/ Pteroylglutamic acid (folacin), vitamin M, vitamin B₉, factor U, L. casei factor, Norite eluate factor. /10/ 0.083 µg vitamin K₁ = one Dam unit. /11/ Nicotinic acid (niacin) and nicotinic acid amide (nicotinamide). /12/ Includes pyridoxine, pyridoxal, pyridoxamine. /13/ Range of means.

35. MILK, CHEMICAL COMPOSITION: VARIOUS ANIMALS

Values are grams per 100 grams whole milk.

Animal	Water	Protein	Fat	Lactose	Ash	Animal	Water	Protein	Fat	Lactose	Ash
1 Anteater	63	11	20	0.3	0.8	14 Horse	90.1	2.6	1.0	6.9	0.35
2 Bison	86.9	4.8	1.7	5.7	0.9	15 Llama	86.5	3.9	3.2	5.6	0.8
3 Buffalo	82.1	5.9	7.9	4.7	0.78	16 Monkey	88.4	2.2	2.7	6.4	0.18
4 Camel	87.7	3.5	3.4	4.8	0.71	17 Mule	90	2.0	1.8	5.5	0.47
5 Cat	81.6	10.1	6.3	4.4	0.75	18 Orangutan	88.5	1.4	3.5	6.0	0.24
6 Deer	65.9	10.4	19.7	2.6	1.4	19 Pig	82.8	7.1	5.1	3.7	1.1
7 Dog	76.3	9.3	9.5	3.0	1.2	20 Rabbit	71.3	12.3	13.1	1.9	2.3
8 Dolphin	44.9	10.6	34.9	0.9	0.53	21 Rat	72.5	9.2	12.6	3.3	1.4
9 Donkey	90.3	1.7	1.4	6.2	0.4	22 Reindeer	64.8	10.7	20.3	2.5	1.4
10 Elephant	70.7	3.6	17.6	5.6	0.63	23 Seal	46.4	9.7	42.0		0.85
11 Fox	81.6	6.6	5.9	4.9	0.93	24 Sheep	82.0	5.6	6.4	4.7	0.91
12 Guinea pig	81.9	7.4	7.2	2.7	0.85	25 Whale	64.8	11.1	21.2	1.6	1.7
13 Hippopotamus	90.4		4.5	4.4	0.1	26 Zebra	86.2	3.0	4.8	5.3	0.7

36. BLOOD: PHYSICAL PROPERTIES

Values in parentheses are estimate "b" or "c" of the 95% range when so designated by superscript (cf Introduction).

Part I: GENERAL

Property	Animal	Blood ¹	Value	Temp ² °C	Property	Animal	Value mm of water
Specific gravity	Vertebrates	Whole	1.056(1.052-1.061) ^b	25/4	Osmotic pressure, serum colloids	Mammals	
	Man	RBC	1.093(1.089-1.097) ^b	25/4		Man	330(280-480) ^c
		Plasma	1.024(1.022-1.026) ^b	25/4		Cat	300(240-330) ^c
	Cat	Whole	1.051(1.045-1.057) ^b	25/4		Cattle	280(260-300) ^c
		Whole	1.052(1.046-1.058) ^b	20/4		Dog	310(230-470) ^c
	Cattle	RBC	1.084(1.079-1.090) ^b	20/4		Goat	300(300-310) ^c
		Plasma	1.029(1.026-1.033) ^b	20/4		Guinea pig	250(230-280) ^c
	Dog	Whole	1.052			Horse	280(230-350) ^c
		Whole	1.042(1.035-1.049) ^b	25/4		Rabbit	290(230-350) ^c
	Goat	Plasma	1.022(1.019-1.025) ^b	25/4		Rat	260(220-290) ^c
		Whole	1.053(1.046-1.059) ^c	20/4		Sheep	300(290-340) ^c
	Horse	Plasma	1.027(1.025-1.028) ^c	20/4		Swine	330(300-350) ^c
	Mouse	Whole	1.057(1.052-1.062) ^b	25/4		Birds	
		Whole	1.050(1.048-1.052) ^b	25/4		Chicken	150(140-160) ^c
	Rabbit	RBC	1.098(1.093-1.104) ^b			Dove	110(80-120) ^c
		Plasma	1.025(1.018-1.031) ^b	74		Reptiles	
	Rat	Whole	1.054(1.046-1.061) ^b	25/4		Turtle (Malacoclemmys), spring fall	58(48-68) ^c 96(80-110) ^c
		Plasma	1.023(1.018-1.028) ^b	25/4		Amphibians	
	Sheep	Whole	1.051(1.041-1.061) ^b	20/4		Frog (Rana catesbiana)	103(95-115) ^c
		RBC	1.084(1.080-1.087) ^c			Frog (R. temporaria)	70(to 140) ^c
		Plasma	1.028(1.025-1.029) ^c			Toad (Bufo vulgaris)	133(85-240) ^c
	Swine	Whole	1.046(1.039-1.054) ^b	25/4		Fish, fresh-water	
		Plasma	1.022(1.019-1.025) ^b	25/4		Carp, common (Cyprinus carpio)	100-115
	Chicken	Whole	1.056(1.050-1.064) ^c			Eel (Anguilla anguilla)	225
		Plasma	1.019(1.017-1.021) ^c			Pike (Esox lucius)	110-145
	Invertebrates					Tench (Tinca vulgaris)	101(95-110)
	Apis ³	Whole	1.045			Fish, salt-water	
	Bombyx ³	Whole	(1.032-1.041)			Bass (Labrax lupus)	175-250
	Calliphora ³	Whole	1.021			Cod (Gadus morrhua)	113(112-114)
	Deilephila ³	Whole	1.031			Eel, conger (Conger conger)	145-175
	Dytiscus ⁴	Whole	1.026			Dogfish, spiny (Squalus acanthias)	42-43
	Gastrophilus ³	Whole	1.062			Mackerel (Scomber scombrus)	196-198
	Hydrophilus ⁴	Whole	1.012			Plaice (Pleuronectes platessa)	115(105-125)
	Periplaneta ⁴	Whole	1.016			Ray, electric (Torpedo marmorata)	42-52
	Phormia ³	Whole	1.018			Scorpion fish (Scorpaena scrofa)	180-185
	Prodenia ³	Whole	1.032			Turbot (Rhombus maximus)	174
Relative viscosity ⁵	Vertebrates	Whole	4.7	38	Freezing point depression, serum	Vertebrates	$\Delta f, p. ^\circ C$
	Man	Plasma	1.8	38		Man	0.562(0.555-0.570) ^c
		Serum	1.5	38		Cattle	0.585
	Cat	Whole	4.2	38		Dog	0.571
	Cattle	Whole	4.6	20		Horse	0.564
	Dog	Whole	4.7	38		Rabbit	0.592
	Goat	Whole	4.0	20		Sheep	0.619
		Whole	4.1	20		Swine	0.615
	Horse	Plasma	1.9	20		Turtle	0.690
		Serum	1.7	20		Fish	
	Rabbit	Whole	3.4	37		Pike	0.514
		Serum	1.4	37		Plaice	0.732
	Sheep	Whole	4.3	20		Tench	0.523
		Plasma	1.6	20		Invertebrates	
		Serum	1.5	20		Aedes aegypti ³	0.4-0.5
	Swine	Whole	5.9	20		Apis mellifera ³	0.86
		Serum	1.6	20		Bombyx mori ³	0.48
	Chicken	Serum	1.4	20		Cancer spp	1.82
		Whole	4.0	20		Culex pipiens ³	0.4-0.5
	Duck	Plasma	1.5	10-14		Dytiscus circumcinctus ⁴	0.56
		Whole	4.6	20		Ephestia elutella ³	1.12
	Goose	Plasma	1.5	12-17		Melolontha vulgaris ³	0.81
		Whole	2.2	20		Popillia japonica ³	1.03
	Turtle	Whole	2.8	15		Ranatra linearis ⁴	0.75
		Serum	1.5	15		Saturnia pyri ³	0.77
	Frog					Venus spp	1.39

Part II: RED BLOOD CELLS

Property	Animal	Value milli-volts	Property	Animal	Value sq cm/volt sec x 10 ⁻⁴	Property	Animal	Value ⁷ mm/hr	Property	Animal	Value ⁷ mm/hr
Electrical charge ⁶	Man	-16.8	Electrophoretic mobility ⁶	Man	1.31	Sedimentation rate (concluded)	Man ♂	(0-9)	Sedimentation time	Rabbit	2(1.5-2.5)
	Cat	-17.8		Cat	1.39		♀	(0-15)		Rat	(0.7-1.8)
	Dog	-21.1		Dog	1.65		Cat	7.3(4-13)		Sheep	0.5(0.5-0.7)
	Guinea pig	-14.2		Guinea pig	1.11		Cattle	1.2(1-1.8)		Swine	5.3(3-8)
	Monkey, rhesus	-17.0		Monkey, rhesus	1.33		Dog	4(2.5-5)		Chicken	3.7(2-6)
	Mouse	-17.9		Mouse	1.40		Goat	0.5		Goose	3.4(2.7-4)
	Rabbit	-7.0		Rabbit	0.55		Guinea pig	1.1(0.7-1.7)		Man	(6-10 hours)
	Rat	-18.6		Rat	1.45		Horse	125(120-135)		Rabbit	(17-42 hours)

/1/ RBC = red blood cells. /2/ For specific gravity, values are for the temperature of measurement referred to water at 4°C. /3/ Larva. /4/ Adult.
/5/ Relative to water at temperature of measurement. /6/ M/15 phosphate buffer at pH 7.4. /7/ Measured at end of first hour.

37. BLOOD, CHEMICAL COMPOSITION: MAN

Values are mg/100 ml (unless otherwise indicated) of blood or blood fraction shown in the column headings. Values in parentheses are ranges, and are estimate "d" of the 95% range unless followed by superscript (cf Introduction).

Constituent		Whole Blood mg/100ml blood	Red Blood Cells mg/100ml RBC	Plasma mg/100ml plasma	Serum mg/100ml serum	Constituent		Whole Blood mg/100ml blood	Red Blood Cells mg/100ml RBC	Plasma mg/100ml plasma	Serum mg/100ml serum
1	Water, g/100ml	83(81-86) ¹	72(70-75) ²	94(93-95)	93(93-94) ^c	50	Creatine	3.9(2.9-4.9) ^b	8.1(6.0-10.2) ^b		(2.5-3.0)
2	Aluminum, µg/100ml	15(7-40)	7(7-17)	46(7-88)		51	Creatinine	0.86	1.8(1.7-1.9) ^b	0.91(0.87-0.95) ^b	(0.7-1.1)
3	Bicarbonate, mEq/L	20.9(19.1-22.7) ^b			27(24-31)	52	Glutamine			(4.6-10.6)	
4	Calcium, mEq/L	4.8	(0.6-1.4)	4.8(4.3-5.2)	5.2(4.8-6.1)	53	Glutathione	34			
5	Chloride, mEq/L	82(71-87)	78	102(93-110)	102(97-108) ^b	54	Histamine, µg/100ml	(6.7-8.6)			
6	Copper, µg/100ml	98(72-125)	115(71-160)	109(75-145)		55	Nucleotides	41(31-52)			
7	Fluoride, µg/100ml	28(11-45)	27(11-44)	28(10-45)		56	Purines, total	10.5			
8	Iodide, µg/100ml	7.7(3-13)			7.1(4.8-8.6)	57	Ribonucleic acid	64(48-79)	135(100-170)	4.9(3.9-5.9)	
9	Iodine, protein-bound, µg/100ml	(4.0-8.5)			5.0(3.6-6.4)	58	Urea	(30-45)	30(25-39) ^b	34(28-40) ^b	(38-54)
10	Iron	48(43-52)		0.1(0.03-0.18)	(0.08-0.15)	59	Uric acid	3.2(2.2-4.2) ^b	1.9(0.8-3.0) ^b	3.8(2.0-5.6) ^b	(4.0-4.8)
11	Lead, µg/100ml	29(18-49)	57(29-86)	2.9(7-7.8)		60	Amino acids, total	50(38-53)			
12	Lithium, µg/100ml	1.9				61	Alanine	4.0(2.8-5.2) ^b	4.0(2.5-5.6) ^b	(2.4-7.6)	
13	Magnesium, mEq/L	3.2(3.0-3.7)	5.1(1.6-6.6)		1.8(1.7-1.9)	62	Arginine	1.0(0.6-1.7) ^b	0.3(0.1-0.6) ^b	(1.2-3.0)	
14	Manganese, µg/100ml	13(0-25)	19(7-48)	8(7-19)		63	Aspartic acid			(0-1.2)	
15	Phosphorus, acid-soluble	23.1(18.6-29)	50(39-59)	23(19-29)	5.1 ³	64	Cystine	0.9(0.6-1.2) ^b	0.4(0.3-0.5) ^b	(1.8-5.0)	
16	Potassium, mEq/L	48(39-62)	95(89-101) ^b	3.6	4.2(3.6-4.8) ^b	65	Glutamic acid			(0-1.3)	
17	Silicon, µg/100ml	235(140-295) ⁴			350(220-570)	66	Glycine	(1.8-2.5)	2.4(1.6-3.1) ^b	(0.8-5.4)	
18	Sodium, mEq/L	83(72-91)	18.6(8.7-28.6) ^b	(140-155)	138(132-144) ^b	67	Histidine	1.3(0.9-1.7)	1.1(0.8-1.6)	(1.0-3.8)	
19	Sulfate, mEq/L			(1.0-1.5)		68	Isoleucine	1.3(0.9-1.5)	0.9(0.5-1.4)	(1.2-4.2)	
20	Tin, µg/100ml	22(7-40)	26(7-64)	4(7-10)		69	Leucine	1.7(1.4-2.0) ^b	1.5(1.0-1.8) ^b	(1.0-5.2)	
21	Zinc, µg/100ml	880(490-1270)	1440(910-1970)	300(0-615)	125	70	Lysine	2.2(1.3-3.0) ^b	1.4(0.9-1.8) ^b	(2.3-5.8)	
22	Protein, total, g/100ml	(19.8-23.8)	36.8	(5.9-7.2)		71	Methionine	0.5(0.4-0.6) ^b	0.5(0.3-0.8) ^b	(0.25-1.0)	
23	Albumin, g/100ml			(6.5-7.4)		72	Phenylalanine	1.0(0.8-1.2) ^b	1.0(0.7-1.3) ^b	(1.1-4.0)	
24	Globulin, g/100ml			4.4(4.0-4.8) ^b	4.3	73	Proline			(1.5-5.7)	
25	Albumin-globulin ratio			2.5(1.8-3.3) ^b	2.9	74	Serine			(0.3-2.0)	
26	α-Globulin, g/100ml			1.7(1.3-2.2) ^b	1.5	75	Threonine	1.6(1.3-2.0) ^b	1.6(1.3-2.1) ^b	(0.9-3.6)	
27	α ₂ -Globulin, g/100ml			0.29(0.2-0.4) ^b		76	Tryptophan	0.7(0.5-1.0) ^b	0.24(0.2-0.4) ^b	(0.9-3.0)	
28	β-Globulin, g/100ml			0.56(0.4-0.7) ^b		77	Tyrosine	1.1(0.8-1.4) ^b	1.1(0.7-1.5) ^b	(0.9-2.4)	
29	γ-Globulin, g/100ml			0.84(0.6-1.1) ^b	1.01	78	Valine	2.4(2.0-2.9) ^b	2.0(1.6-2.5) ^b	(2.5-4.2)	
30	Hemoglobin, g/100ml	(14.0-16.1)	33.5(30-40) ^b	0.90(0.6-1.2) ^b	0.93	79	Ergothioneine	(7-20)			
31	Fibrinogen, g/100ml	0.16		Trace		80	Adenosine triphosphate	(43-53)	(5.9-7.7) mg P		
32	Glycoprotein, acid			0.29		81	Phosphoric acid ester	17.3			
33	Mucoprotein			50		82	Lactic acid	19(0-41)	12	36	
34	Fructose	(0.5-5)			(101-110)	83	Vitamin A ⁷ , µg/100ml	120(20-300)		220(40-540)	
35	Glucose	90(80-100) ^b	74(46-102)			84	Ascorbic acid	0.62(0.2-0.7)	1.0(0.5-2.8)	0.7(0.1-2.5)	
36	Glycogen	5.5(1.2-16.2) ⁵	0	0		85	Biotin, µg/100ml	1.2(0.8-1.7)		1.3(1.0-1.7)	
37	Glucosamine	(60-82)			67(61-78)	86	Cobalamin, µg/100ml	0.08(0.06-0.14)			
38	Mucopolysaccharides			200		87	Choline, total			(26-35)	
39	Lipid, total	560(400-720)	600(410-780) ^b	530(385-675) ^b		88	Choline, free	2.5(1.0-4.0)	(4.4-7.5)	(0.05-2.5)	
40	Fat, neutral	135(85-235) ^b	93(11-150) ^b	140(24-260) ⁶	245(175-325)	89	Vitamin D ⁸ , µg/100ml				2.8(1.7-4.1)
41	Fatty acids			315(295-340)		90	Vitamin E			1.2(0.9-1.9)	
42	Phospholipid	245(185-310)	350(280-420) ^b	165(110-220) ^b	211(180-255)	91	Folic acid, µg/100ml	3.5(2.3-5.3)		1.7(1.5-5.0)	
43	Cephalin	65	210	(7-9)		92	Inositol			0.5(0.4-0.8)	
44	Lecithin	115	70	(117-156)	107	93	Nicotinic acid	0.6(0.2-0.9)	1.3	0.07(0.02-0.15)	
45	Sphingomyelin	185	70	(41-56)		94	Pantothenic acid				
46	Cholesterol, total	(120-210)	175	(195-230)	(130-225)	95	Para-aminobenzoic acid, µg/100ml	30(15-45)	25(15-30)	15(6-35)	
47	Cholesterol esters			146	(121-125)						
48	Ammonia	0.18(0.12-0.24)			(0.2-1.1)	96	Riboflavin, µg/100ml	3.4	22(18-26)	3.2(2.6-3.7)	
49	Bilirubin	0.18(0.1-0.25)				97	Thiamine, µg/100ml	8.0(4-11)	8(7-10)	7(1-9)	

/1/ A range of 80.5-80.8 has been reported. /2/ A value of 66 has been reported. /3/ Inorganic phosphorus. /4/ A value of 830 has been reported. /5/ All localized in granulocytes. /6/ A value of 315 has been reported. /7/ As β-carotene; 0.6 µg = one I. U. /8/ As calciferol; 0.025 µg = one I. U.

38. BLOOD, CHEMICAL COMPOSITION: VERTEBRATES OTHER THAN MAN

Values are mg/100 ml unless otherwise indicated, and are for plasma except where accompanied by the following code: Bl = blood; Ce = cells; S = serum. Values in parentheses are ranges and, unless followed by superscript, are estimate "d" of the 95% range (cf Introduction).

Constituent	Cattle	Dog	Goat	Guinea Pig	Horse	Monkey	Rabbit
1 Water, g/100 ml	85 Bl	84 Bl	81 Bl		81 Bl		86 Bl
2 Calcium, mEq/L	5.4 (4.7-6.1) S	5.3 (4.7-6.1)	(4.5-6) Bl	5.3 (3.7-6.8)	6.1 (5.6-6.7) S		7.0 (5.6-8.0)
3 Chloride, mEq/L	104 (97-111) S	106 (99-110)		105 (98-115)	102 (98-106)	110 (103-118)	105 (92-112)
4 Copper, µg/100 ml	(130-155) Bl				36 (34-37) Bl		85 (74-99) Bl
5 Iodide, µg/100 ml		29 (14-52) S		7.3 S			
6 Magnesium, mEq/L	2.3 (1.0-2.9) S	1.8 (1.3-2.0)		2.0 S	(1.5-2.1) S		2.0 (1.7-2.5)
7 Phosphate, inorg.	(5.6-6.5) S	5.6 (S)	(3-11) Bl	5.3 S	(3.1-5.6) S		5.9 S
8 Potassium, mEq/L	4.8 (3.9-5.8) S	4.4 (3.7-5.8)		7.4 (6.8-8.9) S	3.3 (2.7-3.5) S	3.3 (2.7-4.7)	4.1 (2.7-5.1) S
9 Sodium, mEq/L	142 (132-152) S	150 (135-160)		145 (140-150) S	149 (146-152) S	145 (143-164)	158 (155-165) S
10 Protein, total, g/100 ml	6.9 (5.7-8.3) S	(6.1-7.8)		5.4 (5.0-5.6) S	7.6 (6.6-8.3) S	6.8 (5.9-7.5)	7.2 (6.0-8.3)
11 Albumin, g/100 ml	3.1 (2.3-3.7) S	(3.1-4.0)		3.2 (2.8-3.9) S	3.1 (2.3-3.8) S		4.6 (4.1-5.1) S
12 Globulin, g/100 ml	3.8 (3.0-5.1) S	(2.0-3.3)		2.2 (1.7-2.6) S	4.5 (3.2-5.3) S		2.7 (1.9-3.6) S
13 α-Globulin, g/100 ml	1.1 S	1.2 S			1.4 S		
14 β-Globulin, g/100 ml	1.9 S	1.3 S			2.1 S		
15 γ-Globulin, g/100 ml	2.3 S	0.8 S			1.4 S		
16 Hemoglobin, g/100 ml	11.1 Bl	13.6 Bl	11.4 Bl		10.1 Bl		
17 Fibrinogen, g/100 ml	0.72	(0.42-0.64)		0.33	(0.29-0.43)	(0.25-0.40)	
18 Glucose	46 (36-57) Bl	60 (44-78) Bl	(43-65) Bl	96 (82-107) Bl	73 (54-95) Bl	148 S	85 (67-107) Bl
19 Lipids, total	350 (185-510) ^b	580 (47-725)		170 (94-245) ^b			245 (69-415) ^b
20 Fat, neutral	105 (0-230) ^b			73 (0-145) ^b			105 (7-205) ^b
21 Phospholipid	84 (17-150) ^b			51 (25-77) ^b			78 (13-145) ^b
22 Cephalin	3 S	22					27
23 Lecithin	54 S	370 (300-470)					86 Ce
24 Sphingomyelin	22 S	55 S					38
25 Cholesterol	110 (8-210) ^b	173 (140-215)	(55-200) Bl	32 (21-43) ^b	77 S	118 S	45 (10-80) ^b
26 Non-protein N	(20-40) Bl	(17-38) Bl	(30-44) Bl	39 (30-51)	(20-40) Bl		
27 Amino acid N							
28 Creatinine	(1-2.1) Bl	(1-1.7) Bl	(0.9-1.8) Bl		(1.2-1.9) Bl		15.9 (6.0-25) S
29 Urea N	(6-27) Bl	(10-20) Bl	(13-28) Bl	19 (8-28) S	(10-20) Bl		2.6 (1.0-4.3) S
30 Uric acid	(0.05-2.1) Bl	0.33 (0-0.5) Bl	(0.33-1.0) Bl	2.5 (1.3-5.6) S	(0.9-1.1) Bl		112 Ce
31 Adenosine triphosphate	27 Ce	53 Ce			18 Ce		
32 Diphosphoglyceric acid		133 Ce			140 Ce		194 Ce
33 Phytic acid	0	0		0	0	0	0
34 Lactic acid	(5-20) Bl	(7-29) Bl			(10-16) Bl		
Constituent	Rat	Sheep	Swine	Chicken	Reptile ¹	Frog ²	Fish ³
35 Water, g/100 ml	86 Bl	87 Bl	83 Bl	87 Bl			
36 Calcium, mEq/L	6.2 (5.4-7.2) ^b	5.7 S	(5.5-5.7) S	5.0 (4.6-5.3)	5.4	3.2	10.8
37 Chloride, mEq/L	110 (105-117) S	116	103 (100-105) S	122 (115-140)	122	70	
38 Copper, µg/100 ml	107 ⁴		206 (155-260)	14 S			
39 Iodide, µg/100 ml	3.4			7.2			
40 Magnesium, mEq/L	2.9 (2.0-3.7)	1.9 (1.7-2.1)	2.2 (1.9-3.2) S	(1.4-2.0) S	3.4	7.6	1.3 S
41 Phosphate, inorg.	5.9 S	6.9 S	(5.3-9.6) S	(6.2-7.9) S	3.2 S	6.0 S ⁵	9.0 S
42 Potassium, mEq/L	5.9 (5.4-6.4)	4.8	5.9 (4.9-7.1) S	6.0 (4.6-6.5)	4.6	4.8	
43 Sodium, mEq/L	151 (143-156) S	160	155 (140-160) S	154 (140-175)	140	105	
44 Protein, total, g/100 ml	6.3	5.7	8.7 (7.9-10.3)	(3.6-6.1) S			
45 Albumin, g/100 ml	(3.4-4.3) ^b	3.1	3.8 (2.1-4.6) S	(1.7-2.5) S			
46 Globulin, g/100 ml	(1.8-2.5) ^b	2.3	4.9 (3.9-5.6) S	(1.8-2.9) S			
47 α-Globulin, g/100 ml		0.96 S					
48 β-Globulin, g/100 ml		1.4 S					
49 γ-Globulin, g/100 ml		2.1 S					
50 Hemoglobin, g/100 ml		10.3 Bl	14 S				
51 Fibrinogen, g/100 ml	(0.16-0.34) ^b	0.36					
52 Glucose	(56-76) Bl	(30-57) Bl	(45-75) Bl	(125-205) Bl	(46-88) Bl	(36-49) Bl ⁵	(100-255) Bl
53 Lipids, total	230 (70-415) ^b			520 (340-700) ^b			
54 Fat, neutral	85 (26-145) ^b			225 (63-385) ^b			
55 Phospholipid	83 (36-130) ^b	90 (24-125) ^b	96 (80-130)	155 (84-225) ^b			
56 Cephalin			3 S				
57 Lecithin			72 S				
58 Sphingomyelin			21 S				
59 Cholesterol	52 (28-76) ^b		150 Bl	100 (52-150) ^b			
60 Non-protein N		(20-38) Bl	(20-45) Bl	(20-36) Bl			
61 Amino acid N		(4.6-8) Bl	(8-8.5) Bl	(3.8-9.6) Bl			
62 Creatinine		(1.2-1.9) Bl	(1-2.7) Bl	(0.7-1.2) Bl			
63 Urea N	12.9 (9.6-16.3) S	(8-20) Bl	(8-24) Bl	5.7 Bl			
64 Uric acid	2.5 (1.8-3.0) S	(0.05-1.9) Bl	(0.05-1.9) Bl	4.5 (1.2-7.1) Bl			
65 Adenosine triphosphate	77 Ce	45 Ce	115 Ce	57 Ce	560 Ce ⁶	23 Ce ⁵	167 Ce ⁷
66 Diphosphoglyceric acid	146	<3.5 Ce	190 Ce	0	0		0
67 Phytic acid	0	0	0	250 Ce	95 Ce		
68 Lactic acid	(5-21) Bl	(9-12) Bl					(13-19) ^b Bl

/1/ Turtle (*Terrapene carolina*) except where indicated. /2/ *Rana catesbiana*. /3/ Carp, except where indicated. /4/ A value of 320 has been reported. /5/ Species not specified. /6/ Snake. /7/ Catfish.

39. CHANGES IN STORED PRESERVED BLOOD

Values are for whole preserved human blood kept at 4°C and analyzed within 20 minutes after removal from storage. Blood (Bl), red blood cells (RBC); plasma (Pl). All values derived from Rapoport, S., J. Clin. Invest. 26:591, 1947.

Variable	Preservative ¹	Stored 0 da			Stored 10 da			Stored 20 da			Stored 30 da			Stored 40 da		
		Bl	RBC	Pl	Bl	RBC	Pl	Bl	RBC	Pl	Bl	RBC	Pl	Bl	RBC	Pl
1 pH ²	C	7.4			7.1			7.1			6.7			6.7		
2 CD	CD	7.4			7.1			6.8			6.6			6.6		
3 ACD	ACD	7.1			6.7			6.6			6.6			6.6		
4 Potassium, mEq/liter	C		100	5		75	23		63	32				53	34	
5 CD	CD		100	5		74	20		65	25		60	28			
6 ACD	ACD		90	5		75	12		68	19		60	23			
7 Sodium, mEq/liter	C		25	166		45	149		55	142				58	138	
8 CD	CD		21	158		40	148		47	145		52	142	42	137	
9 ACD	ACD		18	160		25	152		30	148		37	142			
10 Inorganic phosphorus, mg/100 ml	C		0	0		35	7		35	10						
11 CD	CD		0	2		10	3		28	6		29	10			
12 ACD	ACD		5	2		18	5		25	8		27	9			
13 Lactic acid, mg/100 ml	C	20			80			80								
14 CD	CD	10			135			185			210					
15 ACD	ACD	20			90			130			155			170		
16 Glucose, mg/100 ml	C				10 ³			10 ³								
17 CD	CD	720 ⁴			650?			575?			520					
18 ACD	ACD	670 ⁵			600?			550?			470					

/1/ Preservative C: 3.2 g trisodium citrate-di-H₂O, in 100 ml aqueous solution, pH 7.5 (effective toxicity re blood = 141%). Ten ml added to 100 ml blood, increasing blood citrate by 10 mM/liter, and plasma citrate by 17 mM/liter. Preservative CD: 2.13 g trisodium citrate-di-H₂O, plus 5 g glucose anhydrous, in 100 ml aqueous solution, pH 7.5 (effective toxicity re blood = 94%). Fifteen ml added to 100 ml blood, increasing blood citrate by 11 mM/liter, and plasma citrate by 19 mM/liter; blood glucose by 650 mg/100 ml. Preservative ACD: 1.33 g trisodium citrate-di-H₂O, plus 470 mg citric acid, plus 3 g glucose anhydrous, in 100 ml aqueous solution, pH 5.03 (effective toxicity re blood = 66%). Twenty five ml added to 100 ml blood, increasing blood citrate by 13 mM/liter, plasma citrate by 21 mM/liter, blood glucose 600 mg/100 ml, citric acid by 16.5 mEq/liter. Blood changes: Blood preserved with C for 8 days shows changes equivalent to those in blood stored for 18 days with CD, and for 33 days with ACD. /2/ pH measured at 37.5°C. Blood and plasma, same pH. /3/ Residual non-fermentable reducing substances. /4/ Normal blood glucose plus glucose in CD. /5/ Normal blood glucose plus glucose in ACD.

40. BLOOD ENZYME ACTIVITY: VERTEBRATES

Values in parentheses are ranges, and, when accompanied by a literal superscript, are estimates of the 95% range (cf Introduction). B = blood, C = RBC; P = plasma; S = serum.

Animal	Activity/100 ml	Animal	Activity/100 ml	Animal	Activity/100 ml	Animal	Activity/100 ml
1 Rabbit	Adenosine Deaminase ¹	27 Man	Catalase (concluded)	60 Sheep	Cholinesterase ^{14, 15, 16} (concluded)	92 Man	Dehydropeptidase ¹⁸
2 Man	B 415	28 Cow	S 690 ⁹	61 Fowl	C 76	93 Rat	S 359
3 Man	S 41(21-61) ^b	29 Man	B 336 ¹¹	62 Fowl	P 13.0	94 Man	C +
4 Rabbit	Adenosine Polyphosphatase, Acid ²	30 Man	C 547 ¹¹	63 Labrus	C Trace	95 Man	β-Glucuronidase ¹⁹
5 Man	S 30(10-51) ^b	31 Man	P 176 ¹¹	64 Labrus (bony fish)	C 0.3	96 Man	S σ(0-181)
6 Rat, albino	Adenylic Acid Deaminase, Muscle ³	32 Cat	S (135-362) ¹²	65 Scyllium	C 0	97 Rat	S σ(37-230)
7 Rat, albino	B 41	33 Cat	S (92-140) ¹²	66 Scyllium	C 0	98 Rat	Glyoxalase ²⁰
8 Rat, albino	Aldolase ⁴	34 Dog	S (112-303) ¹²	67 Cat (elasmobranch)	P 7.6	99 Rat	C 1,398,000 ²¹
9 Man	S (350-800) ^d	35 Guinea pig	S (125-230) ¹²	68 Man	Cholinesterase ^{15, 17}	100 Rat	Hexokinase
10 Man	C +	36 Horse	S (248-310) ¹²	69 Man	C Trace	101 Rat	C +
11 Rat, albino	C 90,000	37 Mouse	S (430-685) ¹²	70 Cat	P 110	102 Man	Histaminase ²¹
12 Rat, albino	S 6000	38 Ox	S 45 ¹²	71 Cow	P 45	103 Man	S 36(30-40)
13 Rat, albino	Amylase ⁵	39 Swine	S 40 ¹²	72 Dog	C Trace	104 Man	S 18(0-36)
14 Man	S (80-150) ^b	40 Rabbit	S (18-35) ¹²	73 Guinea pig	C 0	105 Man	Lactic Dehydrogenase
15 Man	Arginase ⁶	41 Rat	C 253 ¹³	74 Cat	P 144	106 Rat	C +
16 Man	C 55100	42 Sheep	S 61 ¹²	75 Guinea pig	C Trace	107 Man	S 30(15-50)
17 Man	C 4400	43 Chicken	S (28-78) ¹²	76 Man	P 60	108 Man	Phosphatase, Acid ²⁴
18 Man	B 2000	44 Man	C 261	77 Horse	P 243	109 Man, adult	S (10.5-13.0) ²⁶
19 Monkey	P 0	45 Cat	P 5.8	78 Rabbit	C 0	110 Child	S (5.0-14.0) ²⁸
20 Mouse	C 0	46 Cat	C 12.1	79 Rat	P 19.8	111 Man	Profibrinolysin ²⁹
21 Rat	P +	47 Cow	P 16.2	80 Rat	C 0	112 Man	Vitamin B ₆ Conjugase ³⁰
22 Rat	C 0	48 Dog	C 211	81 Sheep	P 5.8	113 Man	P (80-100)
23 Man	Carbonic Anhydrase ⁷	49 Dog	P Trace	82 Fowl	C Trace		
24 Cat	C 73,000	50 Guinea pig	P 14.8	83 Labrus (bony fish)	C Trace		
25 Calf	C 44,000	51 Guinea pig	C 153	84 Scyllium	C 0		
26 Dog	C 84,000	52 Horse	C 81	85 Cat (elasmobranch)	P Trace		
27 Guinea pig	C 60,000	53 Rabbit	P 8.1				
28 Swine	C 59,000	54 Rat	C 34				
29 Rat	C 144,000	55 Chicken	P 25.2				
30 Chicken	C 22,000	56 Rat	C +				
31 Man	Catalase	57 Man	P 16.2				
32 Man	C 0.18						

/1/ μg N liberated/hr. /2/ μM P from ATP/hr. at pH 4.8 for acid adenosine polyphosphatase, and at pH 8.9 for alkaline adenosine polyphosphatase. Corrected for inorganic P and non-enzymatic hydrolysis. /3/ μg N liberated/hr in presence of 0.05% adenylic acid. /4/ μl fructose diphosphate/hr at 38°C at pH 8.6. No change in pregnancy. /5/ mg dextrose or equivalent (by copper reduction) from starch under specified conditions. /6/ Units as described by Kochakian. Fall in malnutrition. /7/ Amount of RBC that will halve the time of uncatalyzed reaction at 3°C under specified conditions. Fall in newborn; parallels RBC Zn concentration in all conditions in adults. /8/ g/100g dry weight. /9/ Units described by Dille, et al. /10/ mg H₂O₂ split/10 min under conditions specified. /11/ μM acetylcholine hydrolyzed/min as measured by ml 0.01N NaOH required to neutralize acetic acid formed/min from 0.0025M acetylcholine at pH 7.65 at 25°C. /12/ μM acetylcholine hydrolyzed/min from 0.01M acetylcholine. /13/ μM acetylcholine hydrolyzed/min from 0.015M acetylcholine. /14/ μM acetyl-β-methylcholine hydrolyzed/min as measured by volume CO₂ evolved/min from 0.03M acetyl-β-methylcholine. /15/ Hematocrit values of 45 assumed. /16/ RBC cholinesterase activity high in reticulocytes and young cells; high in conditions accompanied by hyperactive hematopoiesis. /17/ μM benzoylcholine hydrolyzed/min as measured by volume CO₂ evolved/min from 0.006M benzoylcholine. /18/ μMNH₃/30 min from α-alanyldehydroalanine at 37°C at pH 8.1. /19/ μg phenolphthalein/hr from phenolphthalein-glucuronide at 38°C at pH 4.5. Rise in pregnancy from 300 μg at 3 months to 1350 μg at term. /20/ μl CO₂/20 min from methylglyoxal at pH 7.2 at 26°C in presence of glutathione. /21/ μg histamine destroyed in 90 min at 37°C. Rise in pregnancy. /22/ ml N/20 NaOH/24 hr from standard olive oil emulsion. /23/ Amount of enzyme which produces color equivalent to 10 μg of p-nitrophenol from p-nitrophenyl sulfate. /24/ mg phenol/hr from disodium phenylphosphate at 37°C at pH 5.0. /25/ Rise in osteoblastic activity and pregnancy. /26/ mg phenol/30 min from disodium phenylphosphate at 37.5°C at pH 9.0. /27/ mg P/hr from β-glycerophosphate at 37°C at pH 8.6. /28/ mg P/hr from β-glycerophosphate at 37°C at pH 8.6. /29/ Units of fibrinolysin. A unit will completely lyse a 0.1% fibrin clot in 120 seconds at 28°C at pH 7.2 in isotonic saline buffered with imidazole. /30/ μg folic acid/90 min from yeast extract at 37°C at pH 4.5.

41. SEROUS FLUIDS, CHEMICAL CHARACTERISTICS: VERTEBRATES

The concentrations in transudates of constituents of blood will depend on the plasma concentration of the constituent, the membrane permeability of the constituent and, in the case of electrolytes, the charge of the ion and the concentrations of non-diffusible ions (proteins) in the plasma and in the transudate. For non-electrolytes readily passing through the membrane, the concentration in transudate water will equal that in plasma water provided a steady state is present. In the case of electrolytes, the concentrations in the transudate will differ from that in plasma according to the Gibbs-Donnan law for heterogeneous solutions. Values are mg/100 ml, unless otherwise indicated. Those in parentheses are ranges, and unless followed by a superscript, are estimate "d" range (cf Introduction).

	Constituent or Property	Animal	Plasma	Transudates	Pleural Fluid	Pericardial Fluid	Peritoneal Fluid
1	Water, %	Man	94 (93-95)	94 (90-99)	98 (96.4-99)		(95-99)
2		Dog	93 (91-95)	98.9 (98.3-99.3)			
3		Horse	91	(93.5-95.8)			
4	Ash, %	Man	(0.6-1.0)		0.76	0.67	0.98
5	pH	Man	7.39 (7.33-7.45) ^b	(7.45-7.68)	7.2 (6.8-7.6)		7.4 (6.8-9.8)
6		Turtle	7.72 (7.46-7.80)			8.25 (7.9-8.5)	8.12 (7.8-8.4)
7		Fish	7.36 (7.2-7.6)	7.45 (7.1-7.6)		6.12 (5.3-6.9)	5.80 (5.4-6.3)
8	Conductivity, mhos x 1000	Man	(10.5-12.4)	14.2 (11.3-15.5)			13.4 (13.2-13.5)
9	Calcium, mEq/L	Man	4.8 (4.3-5.2)	4.0 (2.6-4.9)			
10		Dog	5.3 (4.7-6.1)	3.5 (3.2-4.1)	4.3 (2.8-5.4)		4.0 (2.0-4.9)
11		Turtle	5.4 (3.1-6.5)	2.4		2.1 (0.6-4.5)	3.4 (2.4-5.2)
12		Fish	4.9 (2.9-6.0)	4.6 (3.0-6.9)		1.4 (0.5-3.5)	3.4 (1.7-6.6)
13	Carbon dioxide, mEq/L	Man	29.5 (23-33)	28.7 (22-37)	23.8 (21-31)		26.7 (24-29)
14		Dog	24 (17-27)	26.1 (21-31)			21.4 (10-30)
15		Turtle	40.4 (23-52)	44		88.5 (29-130)	68.9 (24-130)
16		Fish	8.2 (6-12)	7.3 (5-10)		0.4 (trace-0.5)	0.3 (trace-0.4)
17	Chloride, mEq/L	Man	102 (93-110)	105.8 (98-110)	100 (92-135)	124.8	109 (91-120)
18		Dog	106 (99-110)	126 (119-127)			124 (110-145)
19		Turtle	112	75.6		55.1 (15-130)	70.8 (33-125)
20		Fish	236 (225-265)	262 (245-280)		370 (365-375)	274 (190-330)
21	Magnesium, mEq/L	Man	1.8 (1.7-1.9)	2.0 (1.6-2.4)	1.7 (0.7-2.4)		0.5
22		Dog	1.8 (1.3-2.0)	1.7 (1.4-2.2)			
23		Turtle	3.4 (0.5-7.9)	0.8		1.1 (0.3-3.5)	2.1 (0.3-5.0)
24		Fish	2.8 (1.7-3.5)	1.0 (0.9-1.0)		2.6 (1.0-5.0)	17.8 (8.0-25.0)
25	Phosphorus, total	Man	23 (19-29)		11.4 (6-31)		
26		Dog	26	(12-18)			
27	Phosphorus, inorg.	Man	3.4 (2.4-4.4)	3.0 (1.2-4.4)	3.8 (2.1-5.1)		4.0 (1.2-5.3)
28		Fish	19.8 (9-40)	12	5.6 (0-11)	4.3 (0-8.7)	5.6 (0-11)
29	Potassium, mEq/L	Man	3.6	3.4 (2.8-6.0)	4.8 (2.5-6.6)		4.1 (2.0-5.6)
30		Dog	4.4 (3.7-5.8)	5.0 (4.2-6.1)			
31		Turtle	4.6 (2.4-6.7)	2.0		3.1 (1.1-6.1)	3.2 (2.4-4.3)
32		Fish	5.3 (4.5-6.8)	4.8 (3.8-6.0)		16.6 (8.5-22)	6.6 (5.2-8.9)
33	Sodium, mEq/L	Man	(140-155)	140 (120-155)	140 (135-150)		138 (125-155)
34		Dog	150 (135-160)	150 (145-155)			
35		Turtle	138 (120-165)	123		140 (130-150)	137 (120-150)
36		Fish	259 (235-275)	266 (260-270)		314	246 (145-305)
37	Nitrogen, total	Man	(3000-3700)	(320-835)	287 (260-340)		150 (45-555)
38		Dog					149 (26-295)
39	Protein, g/100 ml	Man	(6.5-7.4)	0.85 (0.4-1.3)	1.8 (0.3-4.1)	3.3 (0.8-4.9)	2.1 (0.02-4.5)
40		Cat	7.6 (6.1-9.0)			2.4 (2.2-2.7)	(0.6-2.5)
41		Dog	6.7 (6.1-7.8)	3.0 (0.2-4.8)		1.7 (0.8-2.9)	2.6 (1.6-3.7)
42		Monkey	6.8 (5.9-7.5)			1.7 (1.3-2.2)	
43		Rabbit	5.7			2.2 (1.5-3.6)	
44		Rat	6.3			2.1	
45		Chicken	3.6 (2.6-4.6)			3.5	
46	Albumin, g/100 ml	Man	4.4 (4.0-4.8)	2.2	0.97 (0.8-1.2)	2.2	0.88 (0.3-1.6)
47		Dog	(3.1-4.0)			1.0 (0.7-1.5)	
48	Globulin, g/100 ml	Man	2.5 (1.8-3.3)	0.6	0.79 (0.3-1.2)	0.6	0.81 (0.2-1.7)
49		Dog	(2.0-3.3)			0.75 (0.4-1.5)	
50	Albumin-globulin ratio	Man	1.7 (1.3-2.2)	(2.5-3.5)	1.5 (0.9-3.5)		1.1 (0.9-1.6)
51		Dog	1.4				1.6 (0.7-2.6)
52	Euglobulin, g/100 ml	Man	0.2		(0.7-1.1)		
53	Pseudoglobulin, g/100 ml	Man	1.8		(1.8-2.2)		
54	Fibrinogen	Man	0.29	0.03 (0-0.8)	0.1 (0-0.3)	0.03	0.1 (0-0.2)
55		Horse	(0.29-0.43)	(0.04-2.2)			
56	Non-protein nitrogen	Man		(27.5-30)	31 (20-42)		30.2 (20-43)
57		Dog		34 (20-45)			
58		Fish	1090 (1070-1125)	680			870 (760-1015)
59	Amino acid N	Man		6.4	5.6 (4.2-8.9)		
60		Fish	7.5 (5.6-9.4)				(0-2.6)
61	Ammonia	Man	0.18 (0.12-0.24)	1.2			
62	Creatine	Man	0.23 (0-0.8)	3.2	3.0 (2.1-4.9)		
63		Fish	2.9 (1.8-4.2)	2.4			3.9 (3.6-4.2)
64	Creatinine	Man	0.91 (0.87-0.95)	2.4	1.2 (0.7-2.1)		1.2 (1.0-2.0)
65		Fish	(0-0.5)			0	(0-0.7)
66	Purine N	Man		0.39			
67	Urea N	Man	14 (5-22)	14.4	13 (9.8-22)		16 (11.9-21)
68		Dog		11 (9.9-16.5)			
69		Fish	1180 (1045-1300)	970 (555-1240)		1065 (690-1345)	1015 (900-1100)
70	Uric acid	Man	3.2 (2.2-4.2)	4.0 (2.5-5.0)	4.0 (1.9-8.0)		4.2 (1.8-5.3)
71		Dog	0.33	Trace			
72	Lipid, total, g/100 ml	Man	(0.38-6.67)	1.5 (0.7-2.5)			
73	Fatty acids	Man	315 (295-340)		268 (130-430)		
74	Cholesterol	Man	(195-230)	40 (13-60)	147 (20-329)		60 (5-150)
75	17-OH-corticosteroids, µg/100 ml	Man	13 (2-34)	3 (0-11)	8 (0-16)	(5-16)	4.2 (0-9)
76	Phosphatides	Man	165 (110-220)	142			164
77	Lecithin	Man	117	(60-150)	50 (0-125)		40 (0-140)
78	Lactic acid	Man	36	(17-32)	17.8 (11-47)		
79	Bilirubin	Man	0.18 (0.1-0.25)	(0-0.2)	(0.1-0.7)		0.5

42. LYMPH, CHEMICAL COMPOSITION: MAMMALS

Values in this table are the result of a four-year search for data in the field of lymph composition. Numerous gaps point up lack of available information and/or need for research. Values are mg/100 ml, unless otherwise indicated.

Constituent	Species	Thoracic Duct		Skin Lymphatics		Cervical Lymphatics		Right Lymph Duct		Intestinal Lymphatics		Liver Lymphatics		Leg Lymphatics	
		Plasma	Lymph	Plasma	Lymph	Plasma	Lymph	Plasma	Lymph	Plasma	Lymph	Plasma	Lymph	Plasma	Lymph
1 Calcium	Man	9.5	7.7												
2	Dog	10.4	9.2			11.7	9.8								
3 Chloride	Man	335	335												
4	Dog	390	415			410	430								
5 Phosphorus, inorganic	Man	4.0	3.9												
6	Dog	4.3	3.6			5.6	5.9								
7 Potassium	Man	19.1	18.3												
8	Dog		18.7			16.4		21.1							
9 Sodium	Man	290	290												
10	Dog		330			375	360								
11 Protein, g/100 ml	Man	6.0	2.8-3.6		0.7										
12	Cat	7.6	4.8					7.4	4.9	5.8		5.3	5.2		3.3
13	Dog	6.2	4.0			6.2	3.6			5.7	2.8	5.7	4.4	5.5	1.7
14	Rat	5.8	3.1				3.1								
15 Albumin, g/100 ml	Man	3.5	1.6-2.4												
16	Dog	3.6	2.4			3.6	2.4			3.5	1.9	3.4	2.7		
17	Rat	3.9	1.9												
18 Globulin, g/100 ml	Man	2.5	1.2												
19	Dog	2.6	1.5			2.6	1.3			1.6	0.6	1.8	1.3		
20	Rat	1.9	1.2												
21 Fibrinogen, g/100 ml	Man														
22	Dog	0.4	0.2												
23 Prothrombin, % ¹	Man														
24	Dog		51									93		7.6	
25 Amino acids	Man														
26	Dog	2.4	2.4			4.9	4.8								
27 Non-protein N	Man	25.7	23.4												
28	Dog	40.0	39.0			37.5	37.4	30.0	31.0					27.2	26.7
29 Urea	Man														
30	Dog		23.5			21.7	23.5								
31 Creatinine	Man	1.1	1.0												
32	Dog					1.4	1.4								
33 Glucose	Man	135	136												
34	Dog	125	125			125	130			220	220			110	115
35 Non-fermentable reducing substances	Man														
36	Dog					5.5	5.8								
37 Total lipid, g/100 ml	Man														
38	Dog	0.3-0.6	0.2-7.3			0.6	0.3								
39 Fatty acids	Man														
40	Dog					440	240								
41 Cholesterol	Man	120	75												
42	Dog					135	55			72	48				
43 CO ₂ Content	Man														
44	Dog					57 ²	59 ²								
45 pH	Man														
46	Dog					7.3	7.4								

/1/ Percentage of level in plasma. /2/ ml/100 ml.

43. SWEAT, CHEMICAL COMPOSITION: MAN

Values are mg/100 ml of sweat, unless otherwise indicated. Those in parentheses are averages of ranges reported in the literature.

Constituent	Value	Constituent	Value
1 Water, %	(99.2-99.7)	25 Threonine	5.4(1.7-9.1)
2 Calcium	2.1(1-8)	26 Tryptophan	1.1(0.4-1.8)
3 Chloride	(30-300)	27 Tyrosine	3.2(1.2-5.0)
4 Iodine, µg	0.8(0.5-1.2)	28 Valine	3(1.5-4.5)
5 Iron, µg	27(22-45)	29 Reducing substances, as glucose	(2.8-40)
6 Magnesium	0.2(0.14-4.5)	30 Volatile acids, ml 0.1 N	(2.4-5.6)
7 Manganese, µg	6(3-7)	31 Lactic acid	225(45-452)
8 Nitrogen, ammonia	(2.5-35)	32 Ascorbic acid ¹ , µg	(0-200)
9 Nitrogen, total	31(27-64)	33 Biotin, µg	Trace
10 Phosphorus	0.5 (0-2)	34 Choline, µg	(0.3-1.5)
11 Potassium	(21-126)	35 Folic acid group, µg	0.6(0.53-0.88)
12 Sodium	(29-294)	36 Inositol, µg	21(15-36)
13 Sulfur, total	(0.7-7.4)	37 Nicotinic acid, µg	(7-22)
14 Non-protein nitrogen	31(27-64)	38 Pantothenic acid, µg	3.8(2.2-4.4)
15 Amino acid N	2.8(1.6-4.8)	39 p-Aminobenzoic acid, µg	0.24(0.08-1.7)
16 Creatinine	(0.1-1.3)	40 Pyridoxine, µg	(0.08-0.18)
17 Urea	(12-57)	41 Pyridoxal, µg	3.2(0.4-8.25)
18 Uric acid	1.4(0.7-2.5)	42 Riboflavin, µg	(0-0.5)
19 Arginine	13.5(5.8-21.4)	43 Thiamine, µg	0.15(0-0.6)
20 Histidine	8.0(6-10)	44 Specific gravity	(1.001-1.006)
21 Isoleucine	2.3(1.0-3.6)	45 pH	(3.8-6.5)
22 Leucine	2.7(1.2-4.2)	46 Maximum rate of production, ml/min	(17.7-38.2)
23 Lysine	2.3(1.4-3.2)	47 Stimulus to sweating ² , °C	(39-45)
24 Phenylalanine	2.2(1.0-3.5)		

/1/ Includes dehydroascorbic acid. /2/ Thermally induced, average skin temperature at rest.

44. CEREBROSPINAL FLUID: PHYSICAL AND CHEMICAL CHARACTERISTICS
Values are mg/100 ml unless otherwise indicated; those in parentheses are ranges.

Part I: MAN					
Constituent or Property	Value	Constituent or Property	Value	Constituent or Property	Value
1 Volume, ml	(90-150)	22 Protein, total	28(12-43)	43 Isoleucine N	0.01
2 Specific gravity	1.0071(1.0062-1.0082)	23 Cisternal	15	44 Leucine N	0.01
3 Solids, total	1000(850-1700)	24 Lumbar	25(20-40)	45 Lysine N	0.05
4 Freezing point, °C	-0.570(-0.60 to -0.054)	25 Ventricular	10	46 Methionine N	0.004
5 pH	7.4(7.35-7.70)	26 Albumin, % ¹	55(40-70)	47 Phenylalanine N	0.02
6 Pressure, mm H ₂ O	150(70-180)	27 Fibrinogen	0	48 Threonine N	0.03
7 Aluminum	Trace	28 α-Globulin ¹	10(5-20)	49 Tyrosine N	0.01
8 Barium	Trace	29 β-Globulin ¹	12(15-20)	50 Valine N	0.02
9 Bicarbonate	48	30 γ-Globulin ¹	11(5-20)	51 Cholesterol	(0.24-0.50)
10 Boron	Trace	31 X-proteins ^{1, 2}	7(2-15)	52 Fatty acids	(1-3)
11 Calcium	5(4.5-5.2)	32 Non-protein N	19(12-28)	53 Reducing substances ³	70(44-110)
12 Chloride	440(420-450)	33 Creatinine	1.2(0.5-1.9)	54 Fructose	3.4(2.0-7.5)
13 Copper	0.013(0.006-0.02)	34 Urea	11.7(8-28)	55 Hexosamine	9(5-18)
14 Iodine	<0.001	35 Uric acid	(0.07-2.8)	56 Polysaccharides	3.4(2.3-6.8)
15 Magnesium	2.36(2.0-2.6)	36 Amino acid N	1.23	57 Ascorbic acid	0.6(1-8)
16 Phosphorus	1.5(1.2-2.1)	37 Alanine N	0.21	58 Citric acid	0.04
17 Potassium	9.8(8.5-13.2)	38 Arginine N	0.1	59 Lactic acid	17(11-27)
18 Sodium	525(500-545)	39 Cystine N	0.02	60 Pyruvic acid	(0.4-1.0)
19 Strontium	Trace	40 Glutamine N	0.73	61 Acetylcholine	0
20 Sulfur	0.6	41 Glycine N	0.03	62 Cholinesterase ⁴	Present
21 CO ₂ , vol %	59(57-62)	42 Histidine N	0.05	63 Glucuronidase ⁵	Present

/1/ Per cent of total protein. /2/ 2 components migrating in electrophoresis more rapidly than albumin at pH about 8; not lipoproteins. /3/ Includes glucose. /4/ About 1% of serum concentration. /5/ An unidentified esterase is also present.

Part II: VERTEBRATES					
Constituent or Property	Value	Constituent or Property	Value	Constituent or Property	Value
Cat		Dog (concluded)		Monkey (concluded)	
1 Calcium	6	27 Uric acid	0.24	52 Protein, total (concluded)	(8-15)
2 Chloride	425	28 Allantoin	0.30(0.25-0.47)	53 Cisternal fluid	(20-30)
3 Protein, lumbar fluid	17	29 Glucose	63	54 Lumbar fluid	(0.4-6.3)
4 Glucose	58	30 Ascorbic acid	6.6	55 Globulin	54
5 Ascorbic acid	3.8	Goat		56 Glucose	2.3
Cattle		31 Specific gravity	1.0049	57 Ascorbic acid	2.3
6 Specific gravity	1.0065(1.005-1.008)	32 Chloride	410	Rabbit	
7 pH	7.5(7.4-7.6)	33 Protein, lumbar fluid	12	57 Specific gravity	1.005
8 Pressure, mm H ₂ O	(80-150)	34 Glucose	56	58 Chloride	(600-730)
9 Calcium	6(5.2-6.1)	Horse		59 Protein, total	(15-19)
10 Chloride	410	35 Specific gravity	1.0065(1.004-1.008)	60 Non-protein N	(5.6-16.8)
11 Potassium	(11.2-13.8)	36 pH	7.25(7.13-7.36)	61 Glucose	(50-57)
12 Protein, total	(22-27)	37 Pressure, mm H ₂ O	380(270-490)	Shark	
13 Lumbar fluid	34	38 Calcium	6.3(5.5-7)	62 Specific gravity	(1.0233)
14 Albumin	(10-22)	39 Chloride	450	63 pH	7.2
15 Non-protein N	16	40 Magnesium	2.0(1.1-2.9)	64 Uric acid	0.14
16 Creatinine	1.4	41 Phosphorus, inorganic	1.4(0.9-2.2)	Sheep	
17 Urea	11	42 Potassium	12.7(10.6-14.2)	65 Calcium	5.8
18 Glucose	(48-68)	43 Protein, total	47.6(29-72)	66 Chloride	(750-870)
Dog		44 Cisternal fluid	50(30-66)	67 Magnesium	2.9
19 Specific gravity	1.0065(1.006-1.009)	45 Albumin	38.6(22.6-68)	68 Protein, total	(8-70)
20 pH	7.37(7.35-7.39)	46 Globulin	9.3(3.4-18.4)	69 Non-protein N	29(9.6-42)
21 Pressure, mm H ₂ O	145(30-230)	47 Urea	(23-31)	70 Glucose	(48-110)
22 Chloride	410	48 Glucose	56(49-76)	Swine	
23 Protein, cisternal fluid	30	49 Ascorbic acid	1.7	71 Protein, total	(24-29)
24 Protein, lumbar fluid	12	Monkey		72 Albumin	(17-24)
25 Albumin	(10-25)	50 Chloride	420	73 Globulin	(5-10)
26 Globulin	9	51 Protein, total	(8-50)	74 Glucose	(45-85)

45. SEBUM, CHEMICAL COMPOSITION

Sebum denotes the lipid obtained by extracting the intact skin or hair or wool; in birds, the lipid is from the preen gland oil. Values are g/100 g; those in parentheses are ranges.

Constituent	Man ¹	Guinea Pig	Ox	Rabbit	Rat	Sheep	Duck	Goose
1 Fatty acids, free, total	28.3(22.0-32.2)	8.2	5.1	9.0	7.4	11.0		
2 Straight-chain	28.3							
3 Branched-chain	0							
4 Fatty acids, combined ² , total	34.6(27.5-41.0)	50.5	53.4	43.6	51.4	44.0	47.6	47.5
5 Straight-chain	34.6					3.5	14.8	9.5
6 Branched-chain	0					25.0	32.8	38.0
7 Hydroxy	0					15.0		
8 Triglycerides	32.5	0		0	0	0		
9 Unsaponifiable matter, total	30.1(25.1-35.9)	36.7	42.7	45.9	41.4	(40-50)		
10 Squalene	5.5(3.3-11.2)	0		0	0	0(?)		
11 Hydrocarbons	8.1(5.0-20.0)	1.5		3.4	1.5	<1		
12 Aliphatic alcohols, total	6.2(4.7-6.9)	2.6		30.3	16.9	9.0	48.0	48.0
13 Straight-chain	2.4					1.5	48.0	48.0
14 Branched-chain	3.8					7.5	0	0
15 Cholesterol	4.1(2.7-6.9)	15.0 ³	14.4	3.9	10.1 ³	10.0(4.6-12.5)	1.4	0.25
16 Dihydrocholesterol	0.1					2.5		
17 Isocholesterol ⁴	0			0		12.5		
18 Aliphatic diols						2.5		

/1/ Adult forearm. /2/ As triglycerides, waxes and other esters. /3/ Cholesterol plus Δ⁷-isomer. /4/ A mixture of lanosterol, dihydrolanosterol, agnosterol, and dihydroagnosterol. Also present in sebum of goat (2.5%), camel (2.2%) and llama (1.2%).

46. SYNOVIAL FLUID, PHYSICAL AND CHEMICAL CHARACTERISTICS: MAMMALS

Values in parentheses are estimate "d" of the 95% range (cf Introduction).

Constituent or Property		Man, Knee Joint	Cattle Astragalotibial Joint	Horse Astragalotibial Joint	Constituent or Property		Man, Knee Joint	Cattle Astragalotibial Joint	Horse Astragalotibial Joint
1	Volume, ml	1.1(0.13-3.5)	25(5-65)	(5-40)	16	CO ₂ , mm Hg		58.8(50-70)	
2	Solids, total, %	3.4(1.2-4.8)	2.1(1.7-3.9)		17	Base, total, mEq/L		165(150-180)	
3	pH	7.39(7.29-7.45)	7.31(7.27-7.43)		18	Protein, total, g/100 ml	2.8	0.9(0.4-1.4)	1.4(0.9-1.9) ⁴
4	Viscosity, relative	235(5.7-1160) ¹	5(2-12) ²	(3-29) ^{3,4}	19	Albumin, g/100 ml	1.9	0.71(0.5-0.9)	1.2
5	Specific gravity	(1.008-1.015)	(1.009-1.012)		20	Globulin, g/100 ml	0.9	0.2	
6	Freezing point, °C		(-0.51 to -0.55)		21	β-Globulin, g/100 ml			0.32
7	Osmotic pressure, mm H ₂ O		150(125-170)		22	α-Globulin, g/100 ml			0.37
8	Bicarbonate, mEq/L		28.5(25-32)		23	Fibrinogen	0	0	
9	Calcium, Fl/Se ⁵	0.87	0.83	0.97	24	Mucin, g/100 ml	0.85	0.14(0.03-0.25)	0.47(0.3-0.7) ⁴
10	Chloride, Se/Fl ratio ⁶	0.98	0.99	0.98	25	Mucin, N, g/100 ml	0.1(0.07-0.13)	(0.06-0.2)	0.04(0.03-0.05)
11	Magnesium, mEq/L		1.4(1.3-1.7)		26	Mucin glucosamine, g/100 ml	0.07(0.05-0.13)	(0.02-0.05) ⁸	
12	Phosphorus, mEq/L		2.2(1.5-3.0)	2.6(1.8-3.6) ⁷	27	Non-protein N, Se/Fl ratio ⁶	0.91	0.87	1.05
13	Potassium, mEq/L	4.0	4.0(3.6-4.4)		28	Uric acid, mg/100 g	3.9	1.5(1.2-2.1)	5.3(5-5.6)
14	Sodium, mEq/L	135	145(140-148)		29	Sugar, reducing, mg/100 g	Same as plasma	65(45-95)	(77-82)
15	Sulfate, mEq/L		5.0(4.5-5.4)		30	Hyaluronic acid, mg/100 g	155(4-295)	(20-25)	56

/1/ Hess and Ostwald viscosimeter, 25°C. /2/ Scott-Blair viscosimeter, 20°C. /3/ Hess viscosimeter, 20°C. /4/ Carpal joint. /5/ Square root of distribution ratio: synovial fluid/serum concentration. /6/ Distribution ratio, serum concentration/synovial fluid concentration. /7/ mg/100 g. /8/ Joint not specified.

47. BODY FLUIDS, ELECTROLYTE AND NITROGEN BALANCE IN NORMAL PREGNANCY: MAN

Part I: BLOOD AND URINE

Values are mg/100 ml, unless otherwise indicated; those in parentheses are estimate "b" of the 95% range (cf Introduction).

Constituent or Property		Fluid	Value	Constituent or Property		Fluid	Value	Constituent or Property		Fluid	Value
1	pH	Blood	7.4	10	Protein, total, %	Serum	6.35	19	Creatinine	Blood	1-2
2	Calcium	Serum	9.58	11	Albumin, %	Serum	3.88	20	Ammonia N ²	Urine	3-5
3	Chloride	Serum	580	12	Globulin, %	Serum	2.47	21	Glucose	Blood	80
4	Iodine, µg/100 ml	Plasma	11	13	Fibrinogen, %	Plasma	0.35	22	Lipids, %	Blood	0.9
5	Phosphorus	Serum	3.21	14	Nitrogen, total ¹ , g	Urine	8-12	23	Fat, neutral	Plasma	355(200-500)
6	Potassium	Serum	16.0	15	Non-protein N	Blood	28.0	24	Phospholipid	Plasma	250(160-335)
7	Sodium	Serum	330	16	Urea N	Blood	12.5	25	Cholesterol, ester	Plasma	140(45-235)
8	CO ₂ , vol %	Serum	48	17	Urea N, % of total N	Urine	70-85	26	Cholesterol, free	Plasma	65(35-95)
9	Base, total, mM	Serum	147	18	Uric acid	Blood	3.0	27	Phosphatase, B.U. ³ , %	Serum	6.6

/1/ Per 24 hours. /2/ % of total nitrogen. /3/ Bodansky units.

Part II: AMNIOTIC FLUID

Values are mg/100 ml, unless otherwise indicated.

Constituent or Property	Value
1	Volume, ml
2	Water, %
3	Specific gravity
4	Calcium
5	Phosphorus
6	Sodium
7	Protein, total, %
8	Non-protein N
9	Uric acid
10	Sugar, reducing

/1/ At term.

Part III: FLUID BALANCE

Values are liters, unless otherwise indicated.

Constituent or Property		Value ¹	% of Body Weight
1	Body water ² , total	40	55
2	Extracellular space ³	16	22
3	Sodium space ⁴	20	28
4	Amniotic fluid volume	0.7	
5	Blood volume	5.4	
6	Water content of blood, %	83	
7	Plasma volume ⁵	3.3	4.8
8	Cell volume	1.9	
9	Hematocrit, %	38	

/1/ Average values at term. /2/ Antipyrine volume. /3/ Inulin volume. /4/ Na²⁴ volume. /5/ Gregersen method.

Part IV: ELECTROLYTE AND NITROGEN BALANCE

Values are mg in 24 hr urine sample.

Constituent or Property		Value
1	Calcium	+280
2	Chloride	+0.88
3	Iron	+1-1.5
4	Nitrogen	+1360
5	Phosphorus	+210
6	Potassium	+0.51
7	Sodium	+1.26

48. PROSTATIC FLUID AND SEMEN, PHYSICAL AND CHEMICAL CHARACTERISTICS: MAMMALS

Values are mg/100 ml, unless otherwise indicated; those in parentheses are ranges and, unless accompanied by superscript, are estimate "d" of the 95% range (cf Introduction). Data for additional species are given in the footnotes. (SP) indicates that values are for seminal plasma.

Constituent or Property	Prostatic Fluid		Semen						
	Man ¹	Dog ²	Man	Cattle	Dog	Horse	Rabbit	Sheep	Swine
1 Volume of ejaculate ³ , ml	13-32% of semen	97% of semen	3.5(2.0-6.0)	4.0(2.0-10.0)	6.0(2.0-15.0)	70(30-300)	1.0(0.4-6.0)	1.0(0.7-2.0)	250(150-500)
2 Spermatozoa ³ , millions/ml	0	0	100(50-150)	1000(300-2000)	3000(1000-9000)	120(30-800)	700(100-2000)	3000(2000-5000)	100(25-300)
3 Spermatozoa, size ⁴ , μ			55;5x4x3;5;45	65;9x4x1;13;44	60;7x4x1;10;44	58;7x4x2;10;42	56;9x1x1;9;39		57;8x4x1;11;38
4 Specific gravity	1.022(1.018-1.027)	(1.006-1.008)	1.035(1.031-1.039)	1.034(1.015-1.053)	1.011				
5 Freezing point depression, °C			(0.55-0.58)	0.61(0.54-0.73)	(0.58-0.60)	0.60(0.58-0.62)	(0.55-0.59)	0.64(0.55-0.70)	0.62(0.59-0.63)
6 Conductivity, mho x 10 ⁻⁴			(88-107)	105(90-115)	(129-138)	123(110-130)	94(85-100)	63(50-80)	129(125-135)
7 pH ³	6.5(6.3-6.6)	6.1(5.8-6.5) ^b	7.4(7.1-7.5)	6.9(6.4-7.8)	(6.7-6.8)	7.4(7.2-7.8)	(6.6-7.5)	6.9(5.9-7.3)	7.5(7.3-7.9)
8 Water, g/100 ml	93.2(92.7-93.6)	98.1(97.5-98.7) ^b	91.8(89.1-94.4)	90(87-95)	97.6	97.6		85.2	95.4(94-98)
9 Calcium, mEq/L	60(57-65)	0.6	12(10-14) (SP)	17(12-23)		10		5	(1-3)
10 Chloride, mEq/L	38(35-46)	156(145-170) ^b	43(28-57) (SP)	50	(175-185)	74(24-125)		24	92(42-120)
11 Magnesium, mEq/L			12	10	2	2		2	9(4-12)
12 Phosphorus, total			112(90-120)	82		19		355	66
13 Acid-soluble			57(28-94)	33				170	24
14 Inorganic	(1-2)	Trace	11	9		17		12	2
15 Lipid ⁵	7(6-9)	(1-2)	6	9				29	6
16 Potassium, mEq/L	48(29-61)	5.1(4.7-5.5) ^b	23(17-27) (SP)	44(SP)		17		19	66(22-105)
17 Sodium, mEq/L	153(150-160)	159(155-165) ^b	117(100-135) (SP)	112				45	285(125-370)
18 Carbon dioxide, ml/100 ml	9(7-12)	5(3-6) ^b	54(43-74)	16		24		16	50
19 Trace metals	Zn ⁺	Zn 14(5-22)		Fe 2				Fe 0.8; Cu 0.2; Zn 1.0	
20 Nitrogen, total	415(295-510)	210	915(560-1225)	755		165		875	615(335-765)
21 Proteose			+	+				+	+
22 Fructose ^{6,7}	16(trace-48)	0-30	224(90-520)	500(100-1100)	Trace	15(9-45)	(40-42)	500(275-?)	12(5-25)
23 Lipids, total	286(260-310)	(30-40)			180				
24 Cholesterol	80(62-105)	166(130-210)	80						
25 Sex hormones			♂ +; ♀ +	♂ +		♂ +			
26 Non-protein nitrogen	54(30-90)	22	90(53-130)	48		55		57	22
27 Amino acids, free			+	+ ⁸					
28 Ammonia			2	2		1		2	1
29 Creatine				3		6			
30 Creatinine				12		4			0.3
31 Urea			72 (SP)	4		3		44	5
32 Uric acid			6	6				6	3
33 Ergothioneine			0-trace	0-trace				(0-trace)	15-20
34 Spermine	+		(20-250)	0		0			
35 Citric acid	(480-2700)	30	480(0-2300)	720(200-1700)	Trace	50(30-110)	(110-550)	137(110-260)	140(40-325)
36 Lactic acid			35(20-50)	29(15-43)		15		36	27
37 Ascorbic acid ⁹	(0.5-0.6)	0.8(0.6-0.9) ^b	12.8(11.2-14.4) ^b	6.1(3.0-9.0)				5.1(1.6-8.1)	
38 "B-Vitamins" ¹⁰			+	+					+
39 Nor-adrenalin			0.1-0.2	0.1					
40 Amylase	+	+	+	+	+				
41 Cholinesterase			+	+				++	++
42 Cytochrome ¹¹			+	+			+	+	+
43 β -Glucuronidase	++	+	++	+	+				
44 Hyaluronidase ¹¹			++	+++	+		+++		++
45 5-Nucleotidase			+	+++				+	Low
46 Oxidases	Diamine		Diamine	Xanthine; L-amino-acid					
47 Phosphatase, acid, U/100ml ¹²	(25,000-170,000)	(3-285)	219,000(54,000-420,000)	170(50-340)				+	Low
48 Phosphatase, alk., U/100ml ¹²	Low	(0-107)	Low	390(100-3500)				High	
49 Proteases ¹³	+	+	+	+					
50 Miscellaneous			Heptacosane	Sulfite 8.1					

/1/ Resting fluid. /2/ Pilocarpine stimulated. /3/ Buffalo semen: volume, 2.5(0.5-4.5); sperm no., 630(210-770); pH, 6.3(6.0-6.6)^b. Fox semen: volume, 1.5(0.2-4.0); sperm no., 70(30-250); pH, 6.2-6.4. Goat semen: volume, 0.7(0.5-0.9)^b; sperm no., 2600(650-7500); pH, 6.4(6.0-6.8)^b. /4/ Values are respectively: total length; length x width x thickness of head; length of midpiece; length of tail. Other species: cat, 55; 5 x 3 x 1; 8; 43. Hamster, 155; 13 x 2 x 1; 50; 93. Monkey, 75; 6 x 4 x 2; 11; 59. Rat, 182; 18 x 2 x 1; (?); 164. /5/ Value x 25.8 = total phospholipid. Cephalin content of human prostatic fluid, 107(82-135); ether-insoluble content, 73(63-90). /6/ Prostatic fluid values are for total reducing sugar. Rabbit semen may contain up to 40 mg% glucose. Little, if any, glucose present in semen of other species. /7/ + in semen of goat, guinea pig, hamster, mouse, opossum, rat. /8/ Seminal plasma: alanine, 0.25; aspartic acid, 0.09; glutamic acid, 0.35; glycine, 0.09; histidine, 0.16; phenylalanine, 0.16; serine, 0.13. /9/ Guinea pig, prostatic fluid, 1.5(0.9-2.1)^b; semen, 8.2(6.8-9.6)^b. /10/ Man: choline, 70-2000; inositol, 100. Rat: choline, +. Swine: inositol, 450. Cattle: thiamine, 0.09 (0.03-0.15); riboflavin, 0.21(0.15-0.31); pantothenic acid, 0.37(0.23-0.47); niacin, 0.36(0.25-0.55); inositol, low. /11/ + in rat semen. /12/ U=units; one unit indicates activity for the liberation of one mg phenol from monophenylphosphate in one hr at 37°C; low in rat semen and prostatic fluid. /13/ Prostatic fluid and semen of man and dog contain fibrinogenase and fibrinolysin. Semen of man also contains aminopeptidase and pepsinogenase. Vesiculase is present in rat and guinea pig semen.

49. TEARS, PHYSICAL AND CHEMICAL CHARACTERISTICS: MAN

Constituent or Property			Constituent or Property			Constituent or Property		
Value			Value			Value		
1	Volume, g/16 hr	(0.5-0.67)	12	Vapor pressure, \approx % NaCl	0.93	23	Albumin, %	0.39
2	Volume, σ (15-29 yr), mg/5 min	20+	13	Viscosity, γ	(1.053-1.405)	24	Globulin, %	0.28
3	Volume, φ (12-29 yr), mg/5 min	13+	14	Solids, total, %	1.8	25	Nitrogen, total, %	0.16
4	pH	7.47(7.3-7.7)	15	Dialyzable ¹ , %	0.47	26	Non-protein N, %	0.05
5	Conductivity, \approx % NaCl	0.9	16	Non-dialyzable, %	0.91	27	Urea, %	0.03
6	Freezing point depression, °C	-0.551	17	Ash, %	1.05	28	Ammonia (as NH ₃), %	0.005
7	Osmotic conc., \approx % NaCl	0.9	18	Bicarbonate, mEq/L	26	29	Glucose, true, mg/100 ml	2.5
8	Osmotic pressure, Δ	0.551	19	Chloride, mEq/L	128(118-138)	30	Sugar, reducing, mg/100 ml	6.1
9	Osmotic pressure, \approx mM NaCl	160(150-170)	20	Potassium, mEq/L	24.1(20-28)	31	Lysozyme activity, units ²	1440(800-2500)
10	Refractive index	1.3369	21	Sodium, mEq/L	(142-147)	32	Ascorbic acid, mg/100 ml	0.14
11	Surface tension, n	(0.695-0.749)	22	Protein, total, %	0.67			

/1/ Other than NaCl. /2/ Viscosimetric units.

50. SALIVA, PHYSICAL AND CHEMICAL CHARACTERISTICS: VERTEBRATES

Values are mg/100 ml of the unstimulated, mixed secretion of the salivary glands, unless otherwise indicated. Values in parentheses are estimate "d" of the 95% range (cf Introduction). S=paraffin stimulated.

Constituent or Property			Constituent or Property			Constituent or Property		
Value			Value			Value		
Man			Man (continued)			Dog		
1	pH	6.7(5.6-7.6)	41	Glycine	1.4(0.5-3.6)	80	pH	7.5
2	Specific gravity	7.4(7.2-7.6) S	42	Histidine	(0.35-2.0) S	81	Solids, total	(440-1600)
3	Freezing point, °C	(-0.7 to -0.34)	43	Isoleucine	(0.2-0.9) S	82	Ash	(290-610)
4	Rate of flow, ml/min	0.57(0.1-1.8)	44	Leucine	(0.02-0.3) S	83	Calcium, mEq/L	(2.9-6.6)
5	Solids, total	1.9(0.4-4.8) S	45	Lysine	0.77(0.15-1.5)	84	Chloride, mEq/L	(16.3-70)
6	Ash	580(385-860) S	46	Methionine	(0.005-0.01) S(?)	85	Phosphorus, total	(1.2-3.0)
7	Calcium, mEq/L	(200-220)	47	Phenylalanine	(0.6-2.5) S	86	Potassium, mEq/L	(12.3-23.7)
8	Carbon dioxide, vol %	3.1(2.3-5.5)	48	Proline	(0.35-1.5) S	Goat ²		
9	Chloride, mEq/L	2.8(1.8-4.6) S	49	Serine	0.66(0.33-1.2)	87	pH	(8.1-8.3)
10	Chloride, mEq/L	14.9(8.2-25.3)	50	Threonine	(0.4-5.6) S	88	Specific gravity	(1.002-1.063)
11	Chloride, mEq/L	37.1(19.2-46.0) S	51	Tyrosine	(0.2-1.0) S	89	Solids, total	1300
12	Chloride, mEq/L	15.5(8.4-17.7)	52	Tryptophan	(0.2-0.9) S	90	Ash	520
13	Cobalt, μ g/100 ml	11.8(8.7-17.7)	53	Valine	(0.7-2.2) S	91	Nitrogen, total	(5-22)
14	Copper, μ g/100 ml	2.4(0-12.5) S	54	Glucose	19.6(11.3-28.1)	92	Chloride, mEq/L	(2.8-3.4)
15	Copper, μ g/100 ml	25.6(10-47) S	55	Citric acid	1.0(0.2-3.1) S	Horse		
16	Fluoride, mEq/L	(0-0.005)	56	Lactic acid, mEq/L	0.17	93	pH	(7.3-8.6)
17	Iodine, μ g/100 ml	(0-350)	57	Cholesterol	7.5(3-15)	94	Specific gravity	(1.001-1.008)
18	Magnesium, mEq/L	0.6(0.16-1.06)	58	Ascorbic acid	0.07(0-0.37) S(?)	95	Solids, total ²	1000
19	Phosphorus, total	19.3	59	Biotin, μ g/100 ml	0.08	96	Ash	(100-500)
20	Phosphorus, inorganic	14.9(7.4-21.1)	60	Choline	1.6(0.6-3.6) S	97	Chloride, mEq/L ²	(0.006-0.06)
21	Phosphorus, lipid	(0.05-0.20)	61	Cobalamin, μ g/100 ml	0.33(0.15-0.58) S(?)	Sheep		
22	Potassium, mEq/L	14.1(12.8-16.1)	62	Folic acid, μ g/100 ml	2.4(0.3-7.5) S	98	pH	(8.4-8.7)
23	Sodium, mEq/L	18(14.6-23.8) S	63	Vitamin K, μ g/100 ml	1.5	99	Specific gravity ²	(1.009-1.011)
24	Sodium, mEq/L	17.4(8.7-23.9)	64	Nicotinic acid, μ g/100 ml	11.5(2.3-40.9) S	100	Solids, total	1100
25	Thiocyanate, mEq/L	23.9(7.8-38.3) S	65	Pantothenic acid, μ g/100 ml	8.8(1.2-19) S	101	Ash	(700-900)
26	Nitrogen, total	(2.6-5.2)	66	Pyridoxine, μ g/100 ml	0.6(0.1-1.7) S	102	Nitrogen, total	(4-10)
27	Nitrogen, protein	90(36-125) S	67	Riboflavin, μ g/100 ml	5.0	103	Calcium, mEq/L	(0.8-1.5)
28	Nitrogen, protein	64(23-90) S	68	Thiamine, μ g/100 ml	(0.2-1.4) S	104	Chloride, mEq/L	(7.0-12.1)
29	Mucin	270(80-600) S	69	Amylase, units/ml ¹	100(20-250)	105	Magnesium, mEq/L	(0.5-0.8)
30	Non-protein nitrogen	36.4(8.2-62) S	70	Cholinesterase, units/L ^{2,3}	0.33(0.23-0.43) S	106	Phosphorus, total, mM/L	(37-72)
31	Ammonia, mM/L	3.5(0.8-7.1) S	71	Esterase, total, units/L ^{2,4}	0.34(0.12-0.65) S	107	Phosphorus, inorg., mEq/L ²	52
32	Creatinine	(0.6-1.09)	72	Lipase, units/L ^{2,5}	1.42(0.25-2.58) S	108	Potassium, mEq/L	(4.1-11.8)
33	Urea	8.8(0-14) S	73	Lysozyme, units/L ²	670(250-1360) S	Swine		
34	Uric acid	1.5(0.5-2.9)	74	Phosphatase, acid, units/L ^{2,6}	4.23(2.5-7.7) S	109	pH	(7.1-7.4)
35	Alanine	1.2(0.5-2.9)	Cattle			110	Specific gravity ²	(1.002-1.009)
36	Arginine	(0.16-0.45) S	75	pH	(8.1-8.2)	111	Dry matter, g/100 ml ²	(0.3-4.6)
37	Aspartic acid	(0.16-0.45) S	76	Specific gravity	(1.002-1.009)	112	Ash, g/100 ml ²	(0.1-0.4)
38	Cystine	(0.16-0.45) S	77	Solids, total	880	113	Nitrogen, mM/L ²	(0.04-0.1)
39	Glutamic acid	1.2(0.5-1.3)	78	Bicarbonate, mEq/L	91	Chicken		
40	Glutamic acid	1.2(0.5-1.3)	79	Chloride, mEq/L	4.3	114	pH	(6.7-6.9)

/1/ One unit of amylase is considered as the amount required to digest 5 ml of 1% soluble starch to the achromic point under the conditions of the test. /2/ Parotid gland secretion. /3/ β -Carbo-naphthoxcholine substrate. /4/ β -Naphthyl acetate substrate. /5/ β -Naphthyl laurate substrate. /6/ Monosodium- β -naphthyl phosphate substrate.

51. DIGESTIVE FLUIDS, PHYSICAL AND CHEMICAL CHARACTERISTICS: VERTEBRATES

Unless otherwise indicated values are mg/100 ml; those in parentheses are ranges.

Part I: GASTRIC JUICE

B=basal conditions (absence of all avoidable stimuli); C=caffeine stimulation; F=fasting normal value; FS=stimulated by food; H=histamine stimulation; HS=histamine and sham feeding stimulation; R=hunger juice; S=sham feeding, egg albumin and zein meals; U=fasted.

Constituent or Property		Value	Constituent or Property		Value
Man			Cattle (concluded)		
1	pH	(1.49-8.38)	79	Specific gravity ⁷	(1.002-1.003)
2	Specific gravity	1.006(1.004-1.010)	80	Acidity ⁷ , mEq/L	(36-98)
3	Freezing point, °C	F (-0.3 to -0.8)	81	Nitrogen ⁶ , mg/100 g dry matter	2400
4	Calcium, mEq/L	F 3.6(2.0-4.8)	Dog		
5	Chloride, total, mEq/L	F (78-159)	82	Specific gravity	(1.002-1.004)
6		H (131-170)	83	Freezing point, °C	-0.59(-0.64 to -0.49)
7	Potassium, mEq/L	F 11.6(6.4-16.6)	84	Solids, total	(430-650)
8	Sodium, mEq/L	F 49(18.7-70)	85	Ash	133
9	HCl, free, mEq/L	F (0-115)	86	Organic matter	294
10		H (78-135)	87	Calcium, mEq/L	(0.95-3.3)
11	Acidity, total, mEq/L	F (46-118)	88	Chloride, total, mEq/L	173
12		H (86-137)	89		S 123(98-143)
13	Nitrogen, total, mg/ml	F (0.91-2.18)	90	Phosphorus	R 0.27
14		H (0.73-1.34)	91	Potassium, mEq/L	7.2
15	Nitrogen, α-amino acid	F (5.6-8.4)	92		S 15.2(10.3-22.0)
16		C (7.2-14.4)	93	Sodium, mEq/L	22
17	Protein	B 330	94		S 64(46-79)
18	Alanine	F (1.8-2.7)	95	HCl, free, mEq/L	150
19		C (2.0-2.6)	96	Acidity, mEq/L	S 32(0-50)
20	Arginine	F (3.3-3.6)	97	Nitrogen, total	(50-80)
21		C (3.5-5.0)	98	protein	S (18-19.9)
22	Aspartic acid	F (1.7-2.3)	99	non-protein (NPN)	(9.8-10.9)
23		C (1.6-2.5)	100	total base	(5.4-6.6)
24	Cystine	F (1.8-3.7)	101	volatile base	(1.8-2.6)
25		C (1.6-4.4)	102	non-volatile base	(3.6-4)
26	Glycine	F (1.3-1.6)	103	creatine + creatinine	(0.09-0.11)
27		C (1.2-2.1)	104	histidine-arginine	(1.56-1.77)
28	Glutamic acid	F (2.0-3.2)	105	humic bodies	(3.3-3.7)
29		C (2.6-4.7)	106	lysine fraction	(1.9-2.2)
30	Histidine	F (1.3-2.0)	107	mono-amino fraction ⁸	(0.7-1.02)
31		C (1.3-1.8)	108	purine fraction	(0.10-0.11)
32	Isoleucine	F (0.7-1.4)	109	urea	(0.11-0.16)
33		C (2.3-2.5)	110	Ammonia, mM/L	(1.2-4.6)
34	Leucine	F (1.2-2.2)	111	Arginine, moles ⁹	S (0.08-0.26)
35		C (1.2-3.3)	112	Aspartic acid, moles ⁹	S (0.30-0.68)
36	Lysine	F (1.4-1.8)	113	Glutamic acid, moles ⁹	S (0.81-2.36)
37		C (1.3-1.6)	114	Histidine, moles ⁹	S (0.04-0.08)
38	Methionin	F (0.8-1.5)	115	Isoleucine, moles ⁹	S (1.11-1.93)
39		C (0.9-1.9)	116	Leucine, moles ⁹	S (1.30-3.58)
40	Phenylalanine	F (0.8-1.8)	117	Lysine, moles ⁹	S (0.15-0.26)
41		C (0.7-1.6)	118	Methionine, moles ⁹	S (0.13-0.22)
42	Proline	F (1.7-3.2)	119	Phenylalanine, moles ⁹	S (0.06-0.44)
43		C (2.2-3.3)	120	Proline, moles ⁹	S (0.05-0.21)
44	Serine	F (1.6-2.3)	121	Serine, moles ⁹	S (0.43-0.76)
45		C (1.9-2.1)	122	Threonine, moles ⁹	S 1.00
46	Threonine	F (1.5-2.5)	123	Tryptophan, moles ⁹	S (0.03-0.04)
47		C 2.0	124	Tyrosine, moles ⁹	S (0.3-0.36)
48	Tryptophan	F (1.4-1.9)	125	Valine, moles ⁹	S (1.07-1.30)
49		C (1.2-1.9)	126	Histamine, µg/L	S (4-22)
50	Tyrosine	F (1.0-1.1)	127	Ascorbic acid	0.69(0.33-1.51)
51		C (0.9-1.3)	128	Pepsin, units/ml	S 81(41-164)
52	Histamine, µg/100 ml	(1.3-53.5)	Goat		
53	Fucose	13.8	129	Specific gravity	1.006
54	Glucose, mg/ml	F (0.35-1.19) ¹	130	Acidity, mEq/L	(4-84)
55		H (0.33-1.12) ¹	Horse		
56	Glucuronic acid	2.0	131	HCl, mEq/L	(3.8-5.8)
57	Hexoseamines	33	Sheep ⁶		
58	Hexoses, total	32	132	pH	U (1.05-3.6)
59	Sialic acid	7.31	133	Freezing point, °C	(-0.56 to -0.61)
60	Ascorbic acid	0.95(0.91-1.05)	134	Dry matter, g/100 ml	(3.7-8.2)
61	Lysozyme, µg/ml	7.6(2.6-19.2)	135	Calcium, soluble, mEq/L	(190-335)
62	Pepsin, hemoglobin units/hr	B 4100(0-8, 300) ²	136	Chloride, mEq/L	(141-177)
63	Pepsin, units/ml	(9.7-63) ³	137	Magnesium, soluble, mEq/L	(9.9-18.9)
Cat ⁴			138	Phosphorus, inorganic	(34-100)
64	Solids, total	FS (170-650)	139	Acidity, normal, mEq/L	86
65	Ash	FS (120-380)	Swine		
66	Organic matter	FS (48-265)	140	Ash	(400-800)
67	Calcium, mEq/L	FS (1.7-5.3)	141	Dry matter	(900-2400)
68	Chloride, mEq/L	FS (156-166)	142	Chloride, mEq/L	78
69	Phosphorus	FS (0.16-0.55)	143	Sodium, mEq/L	80
70	Potassium, mEq/L	FS (11.5-13.6)	144	Acidity, mEq/L	100
71	Sodium, mEq/L	FS (12.2-56)	145	Pepsin units ¹⁰	34(4-38)
72	HCl, total, mEq/L	HS (128-155)	Chicken		
73	free, mEq/L	HS (97-122)	146	Acidity, total, mEq/L	H (120-180)
74	Nitrogen	HS (10-41)	147	free, mEq/L	H (80-150)
75	Histamine, µg/100 ml	(2.5-4.5)	Pigeon		
76	Reducing power	(4-37) ⁵	148	Acidity, total, mEq/L	(60-148)
77	Pepsin, Mett units	(0-400) ⁵	149		H (120-195)
Cattle			150	free, mEq/L	(40-136)
78	pH ⁶	(2-4.1)	151		H (70-160)
			152	Pepsin, Mett units	H (0-36)

/1/ After hydrolysis. /2/ Substrate: lyophilized bovine hemoglobin powder. /3/ After test meal; substrate: plasma protein. /4/ Determinations from one animal only. /5/ As glucose. /6/ Abomassal contents. /7/ Calf. /8/ Phosphotungstic acid filtrate. /9/ Avg. moles free amino acid per mole threonine. /10/ Method under investigation.

51. DIGESTIVE FLUIDS, PHYSICAL AND CHEMICAL CHARACTERISTICS: VERTEBRATES (Continued)

Unless otherwise indicated values are mg/100 ml; those in parentheses are ranges.

Part II: BILE

H = hepatic; G = gallbladder; ? = source uncertain.

Constituent or Property			Value	Constituent or Property			Value
Man				Cattle ⁵ (concluded)			
1	pH	H	7.5(6.2-8.5)	80	Cholesterol	G	60
2		G	6.0(5.6-8.0)	81	Lipids, total	G	(100-160)
3	Specific gravity	?	(0.998-1.062)	Dog			
4	Freezing point, °C	?	-0.56	82	pH	H	(7.4-8.5)
5	Specific conductivity ¹	?	(99-137)	83	Specific gravity	H	(1.008-1.015)
6	Surface tension, dynes/cm	?	(39-41)	84	Dry matter	H	(2300-4500)
7	Viscosity, centipoises	?	(0.843-2.342)	85		G	(11,400-24,600)
8	Solids, total	H	2660(1000-4000)	86	Calcium, mEq/L	H	7.3
9		G	11,140(4,700-16,500)	87		G	26.1
10	Dry matter	H	(2300-3300)	88	Chloride, mEq/L	H	64
11		G	18,000	89	Iodine	?	(0.013-0.113)
12	Inorganic matter	H	(200-900)	90	Iron, mEq/100ml	?	(4-8)
13		G	(500-1100)	91	Magnesium, mEq/L	H	3.6
14	Calcium, mEq/L	H	(2.0-4.5)	92	Phosphorus, total	H	(10-15)
15		G	(5.0-7.0)	93		G	(87-280)
16	Chloride, mEq/L	H	(75-110)	94	Potassium, mEq/L	H	6.6
17		G	(15-30)	95	Sodium, mEq/L	H	174
18	Copper	?	(0.063-1.07)	96	Nitrogen, total	H	(65-105)
19	Iodine ²	?	(0.004-0.014)	97		G	(255-635)
20	Iodine ³	?	0.05	98	Proteins, total	H	(130-210)
21	Iron	?	(0.03-7.0)	99		G	(190-520)
22	Phosphorus, total	H	(9-22.3)	100	Allantoin content	?	18.9
23	Potassium, mEq/L	H	4.9	101	Ammonia	?	(0.4-0.6)
24	Nitrogen, total	H	(67-92)	102	Uric acid ⁹	H	(0.37-0.50)
25		G	490	103	Bile salts	H	(500-2400)
26	amino acid	H	5.4	104		G	(7,900-15,000)
27		G	(6.0-21.6)	105	Bilirubin ⁷	H	(42-55)
28	peptide	H	14.0	106		G	(92-170)
29		G	(3.9-27.0)	107	Coproporphyrin	G	147
30	rest	H	45.5	108	Glucides, total	G	(736-938)
31		G	(68-94.0)	109	Sugars, reducing	G	(64-72)
32	Base, total, mEq/L	H	(150-180)	110	Cholesterol	H	(4-15) ⁸
33	Protein, total	H	275	111		G	(80-100)
34		G	(315-540)	112	Fatty acids, total, g/100 ml	H	(0.18-0.27)
35	Urea	H	23.6	113		G	(1.6-5.0)
36		G	(20-45)	114	Lecithins, g/100 ml	H	(250-400)
37	Bile acids	H	(200-1830)	115		G	(2250-7000)
38		G	(1,500-10,000)	116	Choline	H	(39-58)
39	Bile pigment	H	(50-170)	117		G	(340-1110)
40		G	(200-1500)	118	Alkaline phosphatase, units/100 ml ⁴	H	(0-900)
41	Bile salts	H	(650-1400)	Goat			
42		G	11,500	119	Specific gravity	H	(1.004-1.010)
43	Bilirubin	H	(20-200)	120	Dry matter	H	(2880-4720)
44		G	1000	121	Ash	H	(480-760)
45	Coproporphyrin	G	0.01	122	Bile pigment	H	126
46	Mucin and pigment	H	610(430-930)	Goose			
47		G	3420(1800-4300)	123	Solids, total	G	21,950
48	Glucides, total	H	(35-91)	124	Ash and alkali	G	2100
49		G	240	125	Bile acids	G	19,000
50	Sugars, reducing	H	(17-52)	126	Mucin and pigment	G	3100
51		G	80	Guinea Pig			
52	Cholesterol	H	120(80-170)	127	Solids, total	G	2160
53		G	630(350-930)	128	Ash and alkali	G	100
54	Fat, neutral	H	110(40-300)	129	Bile acids	G	780
55		G	370(150-560)	130	Mucin	G	510
56	Fatty acids	H	110(40-300)	131	Lipids, total	G	140
57		G	(150-1090)	Horse			
58	Lecithins	H	(100-575)	132	Specific gravity	H	1.01
59		G	3500	133	Bile pigment	H	33(12-38)
60	Phospholipids	H	60(50-60)	Rabbit			
61		G	200(180-220)	134	pH ⁶	G	(6.4-6.7)
62	Phosphatides	H	(50-80)	135	Specific gravity	G	1.048
63		G	(200-500)	136	Bicarbonate, mEq/L	H	46
64	Choline, total	H	(35-89)	137	Calcium, mEq/L ⁶	H	(4-9.5)
65		G	550	138	Chloride, mEq/L	H	82
Cat				139	Iodine ²	H	(0.004-0.014)
66	pH	H	5.33	140	Iodine ³	H	(0.026-0.069)
67	Chloride, mEq/L	H	12(10-13)	141	Magnesium, mEq/L	H	0.5
68		G	5(0-20)	142	Phosphate, mEq/L	H	2.5
69	Base, fixed, mEq/L	H	17.2(15.7-19.4)	143	Potassium, mEq/L	H	5.7
70		G	27.4(26.1-31.8)	144	Sodium, mEq/L	H	151
71	Bile pigment	H	119(52-218)	145	Sulfate, mEq/L	H	4.4
72		G	(238-1190)	146	Ammonia (fresh bile)	H	(0.22-0.07)
73	Coproporphyrin	G	0.096	147	Bile pigment	H	21.8
74	Alkaline phosphatase, units/100 ml ⁴	G	(190-415)	148		G	(87-131)
Cattle ⁵				149	Sugars, reducing	H	20
75	pH	G	(6.74-7.47)	150	Alkaline phosphatase, units/100 ml ⁴	G	(56-302)
76	Solids, total	G	(8900-9040)	Rat			
77	Ash and alkali	G	(1250-1300)	151	pH ⁸	H	8.3
78	Bile acids, g/100 ml	G	(1550-1700)	152	Specific gravity ⁸	H	1.011
79	Mucin	G	500				

/1/ 30°C; per ohm cm. /2/ Fasting. /3/ Fed. /4/ King-Armstrong units; phenyl phosphate substrate; modified Bodansky method. /5/ Ox. /6/ Fistula bile. /7/ Values obtained by Van den Bergh method. /8/ Average.

51. DIGESTIVE FLUIDS, PHYSICAL AND CHEMICAL CHARACTERISTICS: VERTEBRATES (Continued)

Unless otherwise indicated values are mg/100 ml; those in parentheses are ranges.

Part II: BILE (Concluded)

H = hepatic; G = gallbladder; ? = source uncertain.

Constituent or Property		Value	Constituent or Property		Value
Rat (concluded)			Swine (concluded)		
153	Bilirubin, mg/100 ml/24 hr	H 8.3	169	Bile salts	G 7200
154	Cholesterol, mg/100 ml/24 hr	H 12.7	170	Bilirubin	? (32-62)
Sheep			171	Coproporphyrin	G 0.077
155	pH	H (5.98-6.72)	172	Mucin, pigment, ash	G 1630
156	Bile pigment	H 108	173	Glucides, total	H (120-300)
157		G (50-110)	174	Sugars, reducing	H (37-150)
158	Coproporphyrin	G 0.077	175	Cholesterol	H (130-180)
Swine			176		G 37
159	Solids, total	H (11,500-18,900)	177	Fatty acids, total	H (820-2000)
160		G 10,600	178		G (370)
161	Phosphorus, total	H (48-116)	179	Lecithins	H (1200-2900)
162		G 20.5	180		G 520
163	Nitrogen, total	H (370-480)	181	Lipids, total	G 1800
164		G 266	182	Choline, total	H (180-450)
165	Protein	H (280-410)	183		G 80
166		G 420	Chicken		
167	Bile acids	G 12,000	184	pH	H (6.0-6.2)
168	Bile salts	H (8,500-12,000)	185	Pigment	H 147

Part III: PANCREATIC JUICE

Unless otherwise indicated values are mg/100 ml secretion from pancreatic fistula; those in parentheses are ranges.

Constituent or Property		Value	Constituent or Property		Value
Man ¹			Man ¹ (continued)		
1	pH	7-8	27	Lipase, units/100 ml	(300-2730)
2	Specific gravity	1.008	28	Phosphatase, Bodansky units/100 ml	(0.8-12.7)
3	Freezing point depression, °C	0.625	Dog		
4	Solids, total	(1240-1540)	29	pH	(7.1-8.2)
5	Solids, organic	(380-690)	30	Specific gravity	(1.007-1.014)
6	Ash	(520-860)	31	Freezing point depression, °C	(0.56-0.66)
7	Bicarbonate, mEq/L	(60-75)	32	Solids, total	(1400-6390)
8	Calcium, mEq/L	(2.2-3.2)	33	Solids, organic	480-2220
9	Chloride, mEq/L	(60-80)	34	Ash	840-970
10	Magnesium, mEq/L	0.3	35	Bicarbonate, mEq/L	(15-157)
11	Phosphorus ² , mEq/L	(0.026-1.22)	36	Calcium, mEq/L	(1.8-2.0)
12	Potassium, mEq/L	(4.1-5.6)	37	Chloride, mEq/L	(66-114)
13	Sodium, mEq/L	138	38	Magnesium, mEq/L	(0.2-1.4)
14	Sulfate, mEq/L	8.4	39	Phosphate, mM/L	(0.18-0.5)
15	Protein, total	(190-340)	40	Potassium, mEq/L	(3.0-7.0)
16	Albumin	60	41	Sodium, mEq/L	(151-162)
17	Globulin	40	42	Acid combining power, mEq/L	(58.8-80.4) ⁴
18	Nitrogen	(590-1370)	43	Nitrogen, total	(280-936)
19	non-protein	(28-40)	44	protein	(75-84)
20	urea	(0.5-5.0)	45	non-protein	(18-84)
21	uric acid	0.2	46	Urea	(24-59)
22	Glucose	(8.5-18.0)	47	Glucose	25
23	Proteolytic enzymes, total ³	(9.4-139)	48	Amylase, g maltose/ml juice	(23.9-47.5) ⁴
24	Proteolytic enzymes, active ³	(0.04-16.5)	49	Trypsin, mg tyrosine/ml juice	(407.5-2440) ⁴
25	Trypsin, units/100 ml	(7.1-42.8)	50	Pseudocholinesterase, units/ml ⁵	(420-1080) ⁴
26	Amylase, units/100 ml	(6.4-31.1)			

/1/ Not listed are creatinine, uric acid, copper, SiO₂, and zinc (traces present); cobalt, iron, and nickel (absent). /2/ As HPO₄³⁻. /3/ Trypsin (starch solution substrate for amylase, tributyrin for lipase). /4/ Bodansky units (alkaline) di-sodiumphenyl phosphate substrate; value rises to 200 after fatty meal. /5/ One unit cholinesterase = amount of enzyme liberating 1 µl CO₂/min (0.06M acetylcholine perchlorate substrate).

Part IV: DUODENAL SECRETION

Constituent or Property		Value	Constituent or Property		Value
Man			Man (concluded)		
1	pH ¹	(5.8-7.6)	30	Cholesterol ³ , mg/100 g	36.1(0-315)
2	Volume ² , ml/hr	30	31	Cholic acid, mg/100 g	(130-460)
3	Specific gravity	1.010	32	Bilirubin ³	22.4(0-129)
4	Inorganic matter, mg/g	8	33	Icteric index ³	59(17-299)
5	Solids, total, mg/g	15	34	Amylase ⁴ , glucose units/hr	637
6	Bicarbonate (total CO ₂), mEq/L	(8.4-41)	35	Lipase ⁴ , fatty acid units/hr	179
7	Chloride, mEq/L	(64.2-110.3)	36	Phosphatase ⁵ , units/100 ml	(10-30)
8	Potassium, mEq/L	(1.0-11.0)	37	Proteolytic enzymes, total ⁶	(35-78)
9	Sodium, mEq/L	(84.8-143.4)	38	Active (trypsin) ⁶	(16.4-48)
10	Nitrogen, mEq/L	41	Cat ⁷		
11	Nitrogen, α-amino-	9.2	39	pH	(8.7-8.9)
12	Alanine	3.1	40	Specific gravity	1.009
13	Arginine	2.9	41	Solids, total, mg/g	13.3 ⁷
14	Aspartic acid	3.0	42	Inorganic matter, mg/g	8.42
15	Cystine	4.5	43	Organic matter, mg/g	4.88
16	Glutamic acid	2.2	Dog		
17	Glycine	1.7	44	pH	(6.30-7.28)
18	Histidine	1.2	45	Specific gravity ⁷	1.009
19	Isoleucine	1.1	46	Solids, total ⁷ , mg/g	15.41
20	Leucine	1.2	47	Inorganic matter ⁷ , mg/g	9.26
21	Lysine	2.2	48	Organic matter ⁷ , mg/g	6.15
22	Methionine	2.0	49	Ash, mg/g	7.6-9.4
23	Phenylalanine	1.7	Goat ⁷		
24	Proline	3.0	50	pH	(8.2-8.4)
25	Serine	2.0	51	Specific gravity	1.007, 1.008
26	Threonine	1.8	52	Solids, total, mg/g	14.6
27	Tryptophan	1.1	53	Inorganic matter, mg/g	7.73
28	Tyrosine	0.5	54	Organic matter, mg/g	6.83
29	Valine	1.9			

/1/ Duodenal contents. /2/ Spontaneous; after secretin σ = 181, φ = 126. /3/ Value for fasting adult. /4/ Duodenal contents, Lagerlöf method (starch solution substrate for amylase, tributyrin for lipase). /5/ Bodansky units (alkaline) di-sodiumphenyl phosphate substrate; value rises to 200 after fatty meal. /6/ Casein substrate. /7/ Brunner's glands secretion.

51. DIGESTIVE FLUIDS, PHYSICAL AND CHEMICAL CHARACTERISTICS: VERTEBRATES (Concluded)

Unless otherwise indicated values are mg/100 ml; those in parentheses are ranges.

Part IV: DUODENAL SECRETION (Concluded)

Constituent or Property		Value	Constituent or Property		Value
Rabbit ⁸			Sheep (concluded)		
55	pH ⁸	(8.6-9.0)	64	Acidity, total, mEq/L	(39-62)
56	Specific gravity ⁷	1.009	65	Acid, volatile, mEq/L	(5-19)
57	Solids, total, mg/g ⁷	15.21	66	Chloride, mEq/L	(109-135)
58	Inorganic matter, mg/g ⁷	10.23	Swine		
59	Organic matter, mg/g ⁷	4.98	67	pH ⁸	(8.4-8.9)
Sheep			68	Specific gravity	(1.007-1.008)
60	pH ¹	(2.3-4.7)	69	Solids, total, mg/g ⁷	11.80
61	Specific gravity	1.007	70	Inorganic matter, mg/g ⁷	6.81
62	Dry matter, mg/g	(30-66)	71	Organic matter, mg/g ⁷	4.99
63	Ash, mg/g	(3.9-6.5)			

/7/ Brunner's glands secretion. /8/ From fistula.

Part V: DIGESTIVE ENZYMES

AM = amylase (diastase); CA = carbonic anhydrase; EK = enterokinase; EP = erepsin, peptidases; SU = sucrase; LP = lipase, esterases; MT = maltase; NC = nuclease; PE = pepsin; PH = phosphatase; RI = ribonuclease; RN = rennin (chymosin); TR = trypsin; UR = urease; + = present; - = absent; * = doubtful.

Animal		En- zyme	T = tissue; S = secretion												Animal	En- zyme	T = tissue; S = secretion																
			Salivary Glands		Esoph- agus		Stomach		Pan- creas		Small Intes- tine		Cecum and Colon				Salivary Glands		Esoph- agus		Stomach		Pan- creas		Small Intes- tine		Cecum and Colon						
			T	S	T	S	T	S	T	S	T	S	T	S			T	S	T	S	T	S	T	S	T	S	T	S					
1	Man	AM		+							+	+	±			59	Horse (con- cluded)	LP		+				+									
2		EK									+	+	±			60	PE									-							
3		EP		+								+	+	±			61	AM		+													
4		SU										+	+	±			62	EK									+						
5		LP	+	+	+			+	+			+	+	±			63	EP		+													
6		MT										+	+				64	AM		±						+	+	+					
7		PE										+	+				65	CA					+		+	+	+	+					
8		PH		+													66	EK							+	+	+	+					
9		RN															67	ER							+	+	+	-					
10		TR															68	LP						+	+		±						
11		UR															69	PE									+	-	±				
12	Cat	AM		-							+	+	±			70	PH						+			+	+			+			
13		CA									+			±			71	TR							+			-					
14		EK										+	±	±			72	UR					+										
15		EP										+					73	AM			±				+	+	+	+					
16		SU															74	CA					+		+	+	+	+					
17		LP										+	+				75	EK									+	+	+				
18		MT										+					76	EP									+	+	+				
19		PE											+				77	LP						+		+		+	+				
20		PH	+									±			+	+	78	MT									+	+	+				
21		TR													+	-		79	PE					+			+	+					
22		UR																80	PH								+	+					
23	Cow	AM		±				+	+	+		+					81	TR						+									
24		EK												+			82	UR					+			+	+						
25		LP		+				+	+								83	AM		-					+	+		+					
26		PE			-			+		+				-	+			84	EK		+					+	+				-		
27		PH																85	LP					+	+								
28		RI										+						86	PE			-		+	+	+	+						
29		RN																87	RN					+	± ²		+	+					
30		TR																88	TR							+	±						
31		UR																89	UR						+		+	+					
32		Dog	AM		-				±	+	+		+			±		90	AM			+				+	+		+	+			
33	CA							+						+	+		91	EK							+	+	+	+					
34	EK													+	+		92	EP							+	+	+	+					
35	EP																	93	SU									±					
36	SU																	94	LP		+				+	+		+	±				
37	LP		+					+	+	+	+	+	±			+		95	MT						+	+		+	±				
38	MT											+						96	PE					+	+			+	±				
39	NC											+						97	PH							+	+		+	±			
40	PE																	98	RI							+	+		+	±			
41	PH																	99	RN							+	+		+	±			
42	RI																	100	TR								+	+			-		
43	RN											± ²	+	+		±		101	UR					+			+	+					
44	TR																102	AM		+				+		+	+	+					
45	UR																103	LP						+									
46	Goat	AM		-								±					104	AM			+						+	+	+				
47		EK										+	-				105	EP								+	+		+	-			
48		EP															106	MT								+	+		+				
49		SU															107	PE				+		+	+	+							
50		LP															108	TR								+	+						
51		RN															109	UR						+									
52		TR																110	AM			±				+	+	±	±				
53		UR																111	LP						+	+	+	+	±	-			
54	Guinea pig	AM		+					+		+	+				112	MT								+	+		+					
55		EP															113	PE				+		+	+	+							
56	LP									+		+				114	TR						+	- ¹									
57	Horse	AM		±												115	TR									+							
58		EK												+																			

/1/ In adult. /2/ Young only.

52. VARIOUS CELLS AND CELL PARTS: CHEMICAL COMPOSITION

DNA = deoxyribonucleic acid; RNA = ribonucleic acid.

DNA = desoxyribonucleic acid; RNA = ribonucleic acid.								
Tissue or Cell		Chemical Constituent	Value	Tissue or Cell		Chemical Constituent	Value	
Man				Rabbit (concluded)				
1	Liver, whole cell	DNA phosphorus, $\mu\text{g}/\text{cell}$	1.0	78	Mitochondria (concluded)	Total N, % dry wt of fraction	10.5	
2		RNA phosphorus, $\mu\text{g}/\text{cell}$	4.3	79		Total lipid, % dry wt of fraction	29.6	
3		Total nitrogen, $\mu\text{g}/\text{cell}$	75.3	80	Phospholipid, % dry wt of fraction	17.5		
4		Nucleus	Nucleoprotein, %	42.59	81	Microsome	Total nucleic acid, μg RNA P/mg N	80.0
5	Acidic protein, %		35.51	82	Total N, % dry wt of fraction		9.0	
6	Total protein, "residual," %		4.7-7.5	83	Total lipid, % dry wt of fraction		43.4	
7	Sperm	DNA phosphorus, $\mu\text{g}/\text{sperm}$	0.31	84			Phospholipid, % dry wt of fraction	31.2
8		RNA phosphorus, $\mu\text{g}/\text{sperm}$	0.24	Rat				
Cattle				85	Liver, whole cell	DNA, mg/g fresh tissue	1.92	
9	Liver, beef	DNA phosphorus, $\mu\text{g}/\text{cell}$	0.34	86		DNA, % dry wt	0.7-0.9	
10		RNA phosphorus, $\mu\text{g}/\text{cell}$	0.70	87		DNA phosphorus, mg/g fresh tissue	0.21-0.25	
11	Nucleus	Total nucleic acid, % dry wt	27.5-30.7	88		RNA, mg/g fresh tissue	5.88	
12		DNA, $\mu\text{g}/\text{nucleus}$	6.4	89	RNA phosphorus, mg/g fresh tissue	0.77-1.10		
13		RNA, % dry wt		90	RNA phosphorus, $\mu\text{g}/\text{mg}$ N	27.0		
14	Heart, beef			91	Total protein, mg/g fresh tissue	129.0		
15		Nucleus	DNA, % dry wt	30.0	92	Total lipid, % dry wt	15.2	
16			Total lipid, % dry wt	26.0	93	Phospholipid, % dry wt	8.3	
17			Phospholipid, % dry wt	15.7	94	Cholesterol, % dry wt	2.4	
18	Sperm	Cholesterol, % dry wt	3.6	95	Neutral fat, % dry wt	4.1		
19		Fatty acid, % dry wt	6.5	96	Total nucleic acid, % dry wt	11.4-27.5		
20				97	DNA, % dry wt	4.4-30.0		
21				98	DNA, μg	6.0-11.1		
22	Whole cell	DNA, $\mu\text{g}/\text{cell}$	2.82-3.4	99	DNA, mg/g fresh tissue	1.84		
23		Head	Total nucleic acid, % dry wt	48.0	100	DNA, %	13.0	
24		DNA, $\mu\text{g}/\text{head}$	3.3	101	RNA, % dry wt	2.9-7.6		
25	Thymus, beef	Basic protein, % dry wt	28.7	102	RNA, mg/g fresh tissue	0.64		
26		Nucleus	Acidic protein, "lipo-," % dry wt	19.6	103	Nucleoprotein, mg/g fresh tissue	20.0	
27			Total nucleic acid, % total N	31.0	104	Total lipid, % dry wt	10.5-18.13	
28			Basic protein, % total N	35.0	105	Total lipid, %	3.2-10.0	
29	Thymus, calf	Acidic protein, % total N	14.0	106	DNA, % total nucleic acid	11.7 ¹		
30				107	RNA phosphorus, $\mu\text{g}/\text{mg}$ N	11.0		
31		Whole cell	DNA phosphorus, mg/g fresh tissue	2.24-2.50	108	RNA, % total nucleic acid	19.0-46.0	
32			RNA phosphorus, mg/g fresh tissue	0.80-1.00	109	Total N, %	23.0-38.6	
Dog				110	Total protein, %	30.0-33.0		
33	Liver, whole cell	Total lipid, % dry wt	17.2	111	Total protein, mg/g fresh tissue	35.0-40.0		
34		Phospholipid, % dry wt	9.2	112	Total lipid, % dry wt of fraction	25.0-30.0		
35		Cholesterol, % dry wt	1.07	113	Phospholipid, % dry wt of fraction	66.0		
36		Neutral fat, % dry wt	6.9	114	RNA, % total nucleic acid	50.0		
37	Nucleus	Total lipid, % dry wt	16.5	115	Total nitrogen, %	18.0-20.0		
38		Phospholipid, % dry wt	10.7	116	Total protein, mg/g fresh tissue	19.0-21.0		
39		Cholesterol, % dry wt	1.2	117	Total lipid, % dry wt of fraction	40.0		
40		Fatty acid, % dry wt	4.6	Fowl				
41	Sperm, head	Total nucleic acid, % dry wt	55.3	118	Erythrocytes, nucleus	Total nucleic acid, % dry wt	33.9-38.1	
42		Basic protein, % dry wt	25.0	119		DNA, $\mu\text{g}/\text{cell}$	2.34-2.49	
43		Acidic protein, "lipo-," % dry wt	17.0	120		DNA, %	45.0	
44				121		RNA, % dry wt	0.7-2.5	
Guinea Pig				122	Nucleoprotein, %	50.0-60.0		
45	Liver, whole cell	Total protein, % dry wt	15.0	123	Acidic protein, %	33-40		
46		Mitochondria	Total N, % dry wt of fraction	10.0-12.0	124	Total nucleic acid, % dry wt	29.4-31.2	
47	Microsome	Total lipid, % dry wt of fraction	25.0	125	DNA, $\mu\text{g}/\text{nucleus}$	2.39-2.54		
48		Phospholipid, % dry wt of fraction	16.0	126	RNA, % dry wt	2.0-2.2		
49		Total N, % dry wt of fraction	9.15	127	Sperm, nucleus	DNA, $\mu\text{g}/\text{nucleus}$	1.26	
50		Total lipid, % dry wt of fraction	40.0-51.0	Fish				
51	Microsome	Phospholipid, % dry wt of fraction	28.0-29.0	128	Cod sperm, head	Total nucleic acid, % dry wt	30.3	
52		Phospholipid, % total lipid	58	129		RNA, % dry wt	0.3	
53		Liver, whole cell			130	Herring sperm, head	Total nucleic acid, % dry wt	38.8-59.0
54			DNA, mg/g fresh tissue	2.85	131		RNA, % dry wt	0-1.2
55	RNA, mg/g fresh tissue		9.0	132	Salmon sperm	Total nucleic acid, % dry wt	60.5	
56	RNA phosphorus, $\mu\text{g}/\text{mg}$ N		28.0	133		Whole cell	RNA, % dry wt	0.1
57	Nucleus	Total protein, mg/g fresh tissue	126.3	Sea Urchin				
58		Phospholipid, mg/g fresh tissue	30.1	134	Sperm	DNA, $\mu\text{g}/\text{cell}$	1.0	
59		DNA, %	27.0	135		DNA, % dry wt	15.0	
60		RNA, %	3.4	136	Ovum	DNA, $\mu\text{g}/\text{cell}$	28.0	
61	Mitochondria	Nucleoprotein, %	66.0	137		DNA, % dry wt	0.01	
62		Phospholipid, %	3.4	Bacteria				
63		DNA, % total nucleic acid	5.6 ¹	138	Staphylococcus	Total nucleic acid, % dry wt	11.57	
64		RNA, % total nucleic acid	16.8	139		DNA, % dry wt	2.82	
65	RNA, % dry wt of fraction	3.7	140	RNA, % dry wt		8.75		
66	Total N, %	23.5	141	Total N, % dry wt		13.95		
67	Microsome	Total N, % dry wt of fraction	12.1	142	Total protein, % dry wt	75.5		
68		Total lipid, % dry wt of fraction	27.4	143	Total nucleic acid, % dry wt	4.35		
69		Phospholipid, % of total lipid	56.6	144	DNA, % dry wt	1.15		
70		Cholesterol ² , % of total lipid	12.6	145	RNA, % dry wt	3.20		
71	Microsome	Neutral fat, % of total lipid	30.8	146	Total N, % dry wt	10.0		
72		DNA, % total nucleic acid	14.2 ¹	147	Total protein, % dry wt	58.1		
73		RNA, % total nucleic acid	52.4	148	Total nucleic acid, % dry wt	12.84		
74		RNA, % dry wt of fraction	9.1	149	DNA, % dry wt	3.72		
75	Rabbit	Total N, %	23.1	150	RNA, % dry wt	9.12		
76		Total lipid, % dry wt of fraction	10.3	151	Total N, % dry wt	14.61		
77		Phospholipid, % dry wt of fraction	35.1	152	Total protein, % dry wt	78.5		
78		Cholesterol ¹ , % of total lipid	14.5	153	Salmonella typhosa	Total nucleic acid, % dry wt	13.12	
79	Liver, whole cell	Neutral fat, % of total lipid	22.8	154	DNA, % dry wt	4.40		
80				155	RNA, % dry wt	8.72		
81		DNA phosphorus, mg/g fresh tissue	0.16-0.29	156	Total N, % dry wt	14.40		
82		RNA phosphorus, mg/g fresh tissue	0.44-0.76	157	Total protein, % dry wt	76.8		
83	Mitochondria	Total nucleic acid, μ RNA P/mg N	70.0					
84								
85								
86								

/1/ Contamination with nuclear material cannot be excluded. /2/ Unsaponifiable.

53. BODY FLUIDS, CHEMICAL COMPOSITION: INVERTEBRATES

Part I: INSECTS

Values are for hemolymph and are mg per 100 ml, unless otherwise indicated.

values are for hemolymph and are mg per 100 fl, unless otherwise indicated.									
Constituent	Organism	Stage	Value	Constituent	Organism	Stage	Value		
1	Albumin	Bee, honey (<i>Apis mellifera</i>)	Larva	3400	86	Armyworm, southern (<i>Prodenia eridania</i>)	Larva	165	
2		Beetle, water (<i>Hydrophilus piceus</i>)	Adult	800	87	Bee, honey (<i>Apis mellifera</i>)	Larva	1100	
3	Allantoin	Silkworm, Chinese oak (<i>Antheraea pernyi</i>)	Larva	10	88	Beetle, Japanese (<i>Popillia japonica</i>)	Larva	655-925	
4	Ammonia	Beetle, water (<i>Hydrophilus piceus</i>)	Adult	0	89	Beetle, water (<i>Hydrophilus piceus</i>)	Adult	500-720	
5		Silkworm, Chinese oak (<i>Antheraea pernyi</i>)	Larva	7	90	Cricket, Mormon (<i>Anabrus simplex</i>)	Adult	695	
6	Bicarbonate	Armyworm, southern (<i>Prodenia eridania</i>)	Larva	7.8 ¹	91	Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	1720	
7		Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	90	92	Moth, spurge hawk (<i>Deilephila euphorbiae</i>)	Larva	825	
8		Armyworm, southern (<i>Prodenia eridania</i>)	Larva	37	93	Silkworm (<i>Bombyx mori</i>)	Pupa	415-940	
9		Bee, honey (<i>Apis mellifera</i>)	Larva	14	94	Armyworm, southern (<i>Prodenia eridania</i>)	Larva	1.6-2.5 ¹	
10		Beetle, Japanese (<i>Popillia japonica</i>)	Larva	32	95	Bee, honey (<i>Apis mellifera</i>)	Larva	0.5-0.8 ¹	
11	Calcium	Butterfly, European cabbage (<i>Pieris brassicae</i>)	Larva	23-36	96	Beetle, diving (<i>Dytiscus marginalis</i>)	Adult	Trace	
12		Cricket, Mormon (<i>Anabrus simplex</i>)	Adult	6 ²	97	Beetle, water (<i>Hydrophilus piceus</i>)	Adult	0.11 ¹	
13		Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	11.4	98	Phospholipid	Armyworm, southern (<i>Prodenia eridania</i>)	Larva	99
14		Moth, Cynthia (<i>Samia cynthia</i>)	Pupa	36-38	99	Armyworm, southern (<i>Prodenia eridania</i>)	Larva	125	
15		Moth, pine hawk (<i>Sphinx pinastri</i>)	Pupa	30-33	100	Bee, honey (<i>Apis mellifera</i>)	Adult	180-190	
16		Moth, spurge hawk (<i>Deilephila euphorbiae</i>)	Larva	41	101	Cricket, Mormon (<i>Anabrus simplex</i>)	Adult	180	
17		Silkworm, Chinese oak (<i>Antheraea pernyi</i>)	Pupa	33	102	Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	110	
18	Carbon dioxide	Bee, honey (<i>Apis mellifera</i>)	Larva	26-35 ¹	103	Moth, spurge hawk (<i>Deilephila euphorbiae</i>)	Larva	12.0	
19		Beetle, diving (<i>Dytiscus marginalis</i>)	Adult	7-53 ¹	104	Armyworm, southern (<i>Prodenia eridania</i>)	Larva	17.6	
20		Beetle, water (<i>Hydrophilus piceus</i>)	Adult	55-90 ¹	105	Bee, honey (<i>Apis mellifera</i>)	Larva	32	
21		Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	40-130 ¹	106	Beetle, diving (<i>Dytiscus marginalis</i>)	Adult	10.5	
22		Silkworm (<i>Bombyx mori</i>)	Larva	9-11 ¹	107	Cricket, Mormon (<i>Anabrus simplex</i>)	Adult	110	
23		Armyworm, southern (<i>Prodenia eridania</i>)	Larva	120	108	Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	12.5	
24		Bee, honey (<i>Apis mellifera</i>)	Larva	120	109	Moth, Cynthia (<i>Samia cynthia</i>)	Pupa	11	
25		Beetle, diving (<i>Dytiscus marginalis</i>)	Adult	225	110	Moth, goat (<i>Cossus cossus</i>)	Larva	11.5	
26		Beetle, Japanese (<i>Popillia japonica</i>)	Larva	60-70	111	Moth, pine hawk (<i>Sphinx pinastri</i>)	Pupa	66	
27		Butterfly, European cabbage (<i>Pieris brassicae</i>)	Larva	70-95	112	Moth, spurge hawk (<i>Deilephila euphorbiae</i>)	Larva	30	
28	Chlorine	Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	53	113	Armyworm, southern (<i>Prodenia eridania</i>)	Larva	155	
29		Mosquito, northern house (<i>Culex pipiens</i>)	Larva	170	114	Bee, honey (<i>Apis mellifera</i>)	Larva	95	
30		Mosquito, yellow fever (<i>Aedes aegypti</i>)	Larva	180	115	Butterfly, European cabbage (<i>Pieris brassicae</i>)	Larva	60-120	
31		Moth, goat (<i>Cossus cossus</i>)	Adult	27	116	Cockroach, American (<i>Periplaneta americana</i>)	Adult	70 ²	
32		Moth, pine hawk (<i>Sphinx pinastri</i>)	Pupa	58-63	117	Cricket, Mormon (<i>Anabrus simplex</i>)	Adult	60 ²	
33		Moth, spurge hawk (<i>Deilephila euphorbiae</i>)	Larva	49	118	Fly, flesh (<i>Calliphora erythrocephala</i>)	Larva	145-155	
34		Silkworm (<i>Bombyx mori</i>)	Adult	52	119	Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	45	
35	Cholesterol	Armyworm, southern (<i>Prodenia eridania</i>)	Larva	13	120	Moth, Cynthia (<i>Samia cynthia</i>)	Pupa	160-170	
36		Bee, honey (<i>Apis mellifera</i>)	Larva	33	121	Moth, emperor (<i>Eudia pavonia</i>)	Pupa	155	
37	Citric acid	Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	45	122	Moth, pine hawk (<i>Sphinx pinastri</i>)	Pupa	110-175	
38	Copper	Armyworm, southern (<i>Prodenia eridania</i>)	Larva	4.9	123	Silkworm (<i>Bombyx mori</i>)	Larva	155 ²	
39		Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	0.5	124	Silkworm, Chinese oak (<i>Antheraea pernyi</i>)	Pupa	170	
40	Creatine	Bee, honey (<i>Apis mellifera</i>)	Larva	1.5	125	Worm, cabbage, imported (<i>Pieris rapae</i>)	Larva	290-310	
41	Fructose	Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	280	126	Armyworm, southern (<i>Prodenia eridania</i>)	Larva	66	
42		Moth, wax (<i>Galleria mellonella</i>)	Larva	0	127	Bee, honey (<i>Apis mellifera</i>)	Larva	120-440	
43		Armyworm, southern (<i>Prodenia eridania</i>)	Larva	3.3	128	Beetle, Japanese (<i>Popillia japonica</i>)	Larva	225-285	
44		Bee, honey (<i>Apis mellifera</i>)	Larva	2.8	129	Beetle, water (<i>Hydrophilus piceus</i>)	Adult	25-105	
45	Glycogen	Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	85	130	Cockroach, American (<i>Periplaneta americana</i>)	Adult	55-75	
46		Moth, wax (<i>Galleria mellonella</i>)	Larva	0	131	Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	355	
47		Silkworm (<i>Bombyx mori</i>)	Larva	50	132	Grasshopper, differential (<i>Melanoplus differentialis</i>)	Adult	36	
48	Iron	Moth, spurge hawk (<i>Deilephila euphorbiae</i>)	Larva	5.8	133	Moth, spurge hawk (<i>Deilephila euphorbiae</i>)	Larva	125	
49	Lactic acid	Armyworm, southern (<i>Prodenia eridania</i>)	Larva	Trace	134	Silkworm (<i>Bombyx mori</i>)	Larva	90-230	
50		Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	12-44	135	Armyworm, southern (<i>Prodenia eridania</i>)	Larva	51	
51	Lipids	Armyworm, southern (<i>Prodenia eridania</i>)	Larva	320	136	Bee, honey (<i>Apis mellifera</i>)	Larva	12-17	
52		Bee, honey (<i>Apis mellifera</i>)	Larva	370-585	137	Beetle, Japanese (<i>Popillia japonica</i>)	Larva	35-50	
53		Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	137	138	Cockroach, American (<i>Periplaneta americana</i>)	Adult	245 ²	
54		Moth, spurge Hawk (<i>Deilephila euphorbiae</i>)	Pupa	830	139	Cricket, Mormon (<i>Anabrus simplex</i>)	Adult	50 ²	
55		Armyworm, southern (<i>Prodenia eridania</i>)	Larva	17	140	Fly, flesh (<i>Calliphora erythrocephala</i>)	Larva	365	
56		Bee, honey (<i>Apis mellifera</i>)	Larva	19-22	141	Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	400	
57		Beetle, Japanese (<i>Popillia japonica</i>)	Larva	47	142	Moth, Cynthia (<i>Samia cynthia</i>)	Pupa	4.6-7.3	
58	Magnesium	Butterfly, European cabbage (<i>Pieris brassicae</i>)	Larva	50-110	143	Moth, emperor (<i>Eudia pavonia</i>)	Pupa	7.0	
59		Cricket, Mormon (<i>Anabrus simplex</i>)	Adult	1.7 ²	144	Moth, Mediterranean flour (<i>Ephestia kuehniella</i>)	Larva	37-69	
60		Moth, pine hawk (<i>Sphinx pinastri</i>)	Larva	56-72					
61		Moth, spurge hawk (<i>Deilephila euphorbiae</i>)	Larva	43					

62	Nitrogen gas	Beetle, diving (<i>Dytiscus marginalis</i>)	Adult	1.8 ¹	145	Sodium	Silkworm (<i>Bombyx mori</i>)	Larva	32 ²
63		Beetle, water (<i>Hydrophilus piceus</i>)	Adult	1.9 ¹	146	(concluded)	Silkworm, Chinese oak (<i>Antheraea pernyi</i>)	Pupa	26
64		Armyworm, southern (<i>Prodenia eridania</i>)	Larva	570	147		Worm, cabbage, imported (<i>Pieris rapae</i>)	Larva	21-30
65		Bee, honey (<i>Apis mellifera</i>)	Larva	1450	148	Succinic acid	Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	240
66		Beetle, Japanese (<i>Popillia japonica</i>)	Larva	1150-1400	149		Armyworm, southern (<i>Prodenia eridania</i>)	Larva	44
67		Cricket, Mormon (<i>Anabrus simplex</i>)	Adult	1300	150	Sulfur	Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	9.7
68		Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	1850	151		Beetle (<i>Dytiscus</i> sp)	Whole	1.5-2.0
69		Moth, spurge hawk (<i>Deilephila euphorbiae</i>)	Larva	1200	152	Thiocyanate	Beetle, hydrophilid	Whole	0.75
70		Silkworm (<i>Bombyx mori</i>)	Adult	950-1250	153		Beetle, potato	Whole	3.5
71		Armyworm, southern (<i>Prodenia eridania</i>)	Larva	235	154		Beetle, stag (<i>Lucanus cervies</i>)	Whole	2.9
72		Bee, honey (<i>Apis mellifera</i>)	Larva	250-310	155		Armyworm, southern (<i>Prodenia eridania</i>)	Larva	6.2
73		Beetle, diving (<i>Dytiscus marginalis</i>)	Adult	135	156	Urea	Beetle, water (<i>Hydrophilus piceus</i>)	Adult	2.6
74		Beetle, Japanese (<i>Popillia japonica</i>)	Larva	230-245	157		Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	20.4
75		Beetle, water (<i>Hydrophilus piceus</i>)	Adult	40-80	158		Armyworm, southern (<i>Prodenia eridania</i>)	Larva	14.8
76		Cricket, Mormon (<i>Anabrus simplex</i>)	Adult	260	159		Bee, honey (<i>Apis mellifera</i>)	Larva	4-8
77		Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	95	160		Beetle, diving (<i>Dytiscus marginalis</i>)	Larva	18.0
78		Moth, goat (<i>Cossus cossus</i>)	Larva	235	161		Beetle, water (<i>Hydrophilus piceus</i>)	Adult	11-15
79		Moth, spurge hawk (<i>Deilephila euphorbiae</i>)	Larva	170	162		Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	2.2
80		Armyworm, southern (<i>Prodenia eridania</i>)	Larva	400	163	Uric acid	Moth, spurge hawk (<i>Deilephila euphorbiae</i>)	Larva	18-28
81		Bee, honey (<i>Apis mellifera</i>)	Larva	305-385	164		Silkworm (<i>Bombyx mori</i>)	Larva	5-15
82		Beetle, Japanese (<i>Popillia japonica</i>)	Larva	470-555	165		Silkworm (<i>B. mori</i>)	Pupa	7-15
83		Cricket, Mormon (<i>Anabrus simplex</i>)	Adult	605	166		Silkworm (<i>B. mori</i>)	Adult	13-15
84		Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	130	167		Fly, horse bot (<i>Gasterophilus intestinalis</i>)	Larva	0.9
85		Moth, spurge hawk (<i>Deilephila euphorbiae</i>)	Larva	355	168	Zinc	Silkworm (<i>Bombyx mori</i>)	Larva	1.1-1.3

/1/ Volume per cent. /2/ Serum only.

Part II: MOLLUSKS

Part II: MOLLUSKS				
Constituent	Organism	Fluid ¹	Value ²	
1	Clam, soft shell (<i>Mya arenaria</i>)	U	21.5% tot. N excr.	
2		MF	5% tot. NPN	
3	Sea hare (<i>Aplysia limacina</i>)	U	33.5% tot. NPN	
4		B	11.5% tot. NPN	
5	Slug (<i>Limax agrestis</i>)	U	4.5% tot. NPN	
6	Snail (<i>Helix pomatia</i>)	U	13.7% tot. NPN	
7		B	11-18% tot. NPN	
8	Clam, hard shell (<i>Venus mercenaria</i>)	MF	9.5 mM/liter	
9	Mussel (<i>Anodonta cygnea</i>)	B	8.4 mM/kg H ₂ O	
10	Octopus, lesser (<i>Eledone cirrosa</i>)	B	9.8 mM/liter	
11	Sea hare (<i>Aplysia punctata</i>)	BF	13.3 mM/liter	
12	Carbon dioxide	B	13.5 mm CO ₂ tens.	
13	Clam, hard shell (<i>Venus mercenaria</i>)	MF	515 mM/liter	
14	Mussel (<i>Anodonta cygnea</i>)	B	11.7 mM/kg H ₂ O	
15	Octopus, lesser (<i>Eledone cirrosa</i>)	B	460 mM/liter	
16	Sea hare (<i>Aplysia punctata</i>)	BF	625 mM/liter	
17	Cholesterol	BF	3.6 mg/100ml	
18	Abalone, red (<i>Haliotis refuscens</i>)	B	9-16 mg/100ml	
19	Shell (<i>Busycon canaliculatum</i>)	B	6-12 mg/100ml	
20	Snail (<i>Helix pomatia</i>)	B	19-55 mg/kg meat	
21	Oyster (<i>Ostrea</i> spp)			
22	Clam, hard shell (<i>Venus mercenaria</i>)	MF	25 mM/liter	
23	Mussel (<i>Anodonta cygnea</i>)	B	0.2 mM/kg H ₂ O	
24	Octopus, lesser (<i>Eledone cirrosa</i>)	B	48.7 mM/liter	
25	Sea hare (<i>Aplysia punctata</i>)	BF	53 mM/liter	
26	Octopus (<i>Octopus vulgaris</i>)	HC	16% comp.	
27	Shell (<i>Busycon canaliculatum</i>)	HC	16% comp.	
28	Snail (<i>Helix pomatia</i>)	HC	15% comp.	
29	Octopus (<i>Octopus</i> spp)	HC	22% comp.	
30	Phospholipid	Snail (<i>Helix pomatia</i>)	B	0.7 mg/100ml
31	Clam, hard shell (<i>Venus mercenaria</i>)	MF	7.4 mM/liter	
32	Mussel (<i>Anodonta cygnea</i>)	B	0.5 mM/kg H ₂ O	
33	Octopus, lesser (<i>Eledone cirrosa</i>)	B	11.6 mM/liter	
34	Sea hare (<i>Aplysia punctata</i>)	BF	12.0 mM/liter	
35	Clam, soft shell (<i>Mya arenaria</i>)	B	0.09 g/100ml	
36	Mussel (<i>Anodonta</i> spp)	B	0.07 g/100ml	
37	Sea hare (<i>Aplysia</i> spp)	B	0.28 g/100ml	
38	Snail (<i>Helix</i> spp)	B	2.8 g/100ml	
39	Clam, hard shell (<i>Venus mercenaria</i>)	MF	440 mM/liter	
40	Mussel (<i>Anodonta cygnea</i>)	B	15 mM/kg H ₂ O	
41	Octopus, lesser (<i>Eledone cirrosa</i>)	B	390 mM/liter	
42	Sea hare (<i>Aplysia punctata</i>)	BF	590 mM/liter	
43	Clam, hard shell (<i>Venus mercenaria</i>)	MF	25.6 mM/liter	
44	Mussel (<i>Anodonta cygnea</i>)	B	0.8 mM/kg H ₂ O	
45	Octopus, lesser (<i>Eledone cirrosa</i>)	B	18.5 mM/liter	
46	Octopus (<i>Octopus vulgaris</i>)	U	8-9% tot. NPN	
47	Oyster (<i>Gryphoea angulata</i>)	B	5% tot. NPN	
48	Sea hare (<i>Aplysia limacina</i>)	MF	3.2% tot. NPN	
49	Snail (<i>Helix pomatia</i>)	U	8.7% tot. NPN	
50		U	20% tot. NPN	
51	Octopus (<i>Octopus vulgaris</i>)	B	13-36% tot. NPN	
52	Sea hare (<i>Aplysia limacina</i>)	U	1.4% tot. NPN	
53		U	4.6% tot. NPN	
54	Snail (<i>Helix pomatia</i>)	B	2.6% tot. NPN	
55		U	10.7% tot. NPN	
56	Clams, various	W	77 mg/kg	
	Oyster (<i>Ostrea</i> spp)	W	26-2300 mg/kg	

/1/ B = blood; BF = body fluid; HC = hemocyanin; MF = mantle fluid; U = urine; W = whole organism. /2/ Comp. = composition; excr. = excreted; mM = millimole; NPN = non-protein nitrogen; tens. = tension; tot. = total.

Part III: A PARASITIC NEMATODE

Perivisceral fluid of the roundworm of swine (*Ascaris lumbricoides*). Values are millimoles per liter, unless otherwise indicated; those in parentheses are ranges.

Constituent	Value	Constituent	Value	Constituent	Value
1	Ammonia	7	Hematin	13	Phospholipid
2	Ascorbic acid	8	Iron		123 (120-130) mg/100ml
3	Ash (sulfate)	9	Magnesium	14	Phosphorus, total
4	Calcium	10	Nitrogen, protein		(11.2-12.3)
5	Chloride	11	Nitrogen, non-protein	15	Potassium
6	Glucose	12	Nitrogen, amino		24.6 (16.4-36.6)
				16	Sodium
					130 (120-140)
				17	Urea
					0.17
				18	Zinc
					0.14 (0.13-0.19)

54. CELLS, TISSUES, AND ORGANS: pH VALUES

Methods used in pH determinations are given in the footnotes. Values in parentheses are ranges of values and correspond to estimate "d" of the 95% range (cf Introduction).

Organism and Part		pH	Organism and Part		pH	Organism and Part		pH
Animals			Animals (continued)			Animals (concluded)		
PROTOZOA			MOLLUSCA (concluded)			Ovary, eggs (concluded)		
1	Actinosphaerium eichorni			Chromodoris zebra		165	Stromal cells	6.8(6.7-6.9) ⁶
2	Digestive vacuole (before food)	(6.6-6.9) ¹	81	Nucleus of integument	>5.6(5.6-7.6) ⁸	166	Pancreas, parenchyma	(7.2-7.4) ⁶
3	During digestion	4.3 ¹		Macra solidissima		167	Islet cells	(6.6-6.9) ⁶
4	After digestion	5.4 ¹	82	Cytoplasm	6.8(6.6-7.0) ¹	168	Spleen	6.7(6.5-7.0) ²
5	Amoeba dubia		83	Nucleus	7.4(7.2-7.6) ¹		Mouse (Mus musculus)	
6	Cytoplasm	6.8(6.4-7.2) ¹		Octopus vulgaris		169	Bone	6.8(6.5-7.2) ²
7	Vacuole	7.6 ²	84	Liver cells	7.0 ¹¹	170	Lymph node	<6.2 ²
8	A. limax			Patella picta		171	Muscle, striated	6.0 ¹
9	Exoplasm	7.2 ²	85	Muscle tissue	(5.6-6.0) ¹⁰	172	Spleen	6.7(6.5-7.0) ²
10	Pseudopodia, resting	(7.0-7.2) ^{2, 3}	86	Ciliated cells	7.0 ²		Rabbit (Oryctolagus cuniculus)	
11	After movement	6.8 ^{4, 5}		Sepia officinalis		173	Alimentary canal	6.8 ¹
12	A. polypodia		87	Liver cells	6.0 ¹¹	174	Stomach, chief cells	6.7 ¹
13	Hyaline cytoplasm	(7.2-7.3) ¹		Trochocochlea lineata		175	Parietal cells	6.3 ¹¹
14	A. proteus		88	Cytoplasm	5.2 ¹⁰	176	Duodenum	6.9 ¹¹
15	Cytoplasm	6.9(6.8-7.0) ¹		ARTHROPODA (Crustacea)		177	Ileum	7.1 ¹¹
16	Resting	(6.7-7.3) ⁶		Astacus fluviatilis		178	Cecum	7.0 ¹¹
17	After movement	(6.5-7.0) ²	89	Hepatopancreas	(6.0-6.3) ¹¹	179	Large intestine	7.1 ¹¹
18	Entamoeba coli			Carcinus maenas		180	Liver, peripheral cells	(7.1-7.5) ⁶
19	Cytoplasm	6.7(6.6-6.8) ⁶	90	Hepatopancreas	6.1 ¹¹	181	Central cells	(6.7-7.0) ⁶
20	Endoplasm, resting	6.5 ⁶	91	Muscle fibers	6.8 ¹¹	182	Kupffer cells	(6.4-6.5) ⁶
21	After movement	(6.5-7.0) ⁶	92	Chondrocanthus lophii		183	Pancreas, parenchyma	(7.2-7.4) ⁶
22	Exoplasm, resting	6.8 ⁶		Egg, cytoplasm	5.0 ¹⁰	184	Islets	(6.6-6.9) ⁶
23	After movement	(6.5-7.0) ⁶	93	Maja squinado		185	Uterus, non-pregnant	6.8 ¹⁴
24	Nucleus	7.0 ⁶		Egg, cytoplasm	5.0 ¹⁰		Involuting	6.6 ¹⁴
25	E. histolytica (Human)		94	Platycarcinus pagurus	(5.9-6.8) ¹¹		Rat (Rattus rattus)	
26	Cytoplasm	7.0 ⁷	95	Hepatopancreas	6.1 ¹¹	186	Alimentary canal	6.8(6.6-7.0) ⁶
27	Endoplasm, resting	6.5 ⁶		ARTHROPODA (Insecta)		187	Stomach, chief cells	6.5(6.4-6.6) ⁶
28	After movement	(5.8-6.3) ⁶	96	Chironomus plumosus, larva	(7.1-7.2) ^{2, 6}	188	Parietal cells	(6.8-7.0) ⁶
29	Leishmania donovani		97	Salivary gland cell, cytoplasm	6.9(6.8-6.9) ^{2, 6}	189	Duodenum	7.3 ⁶
30	Cytoplasm	(6.4-6.8) ²	98	Vacuole	6.7(6.7-6.8) ⁶	190	Jejunum	(7.4-7.6) ⁶
31	Nyctotherus cordiformis			Dytiscus marginalis		191	Ileum	(7.4-7.6) ⁶
32	Cytoplasm	(6.8-7.0) ¹	99	Striated muscle cells	6.7(6.7-6.8) ⁶	192	Large intestine	6.8(6.5-7.3) ²
33	Macronucleus	6.0 ²		UROCHORDATA		193	Bone	6.9(6.8-7.0) ¹⁵
34	Pulsating vacuole	7.2(7.0-7.4) ²	100	Ascidia mentula		194	Liver, total tissue	7.3(7.1-7.5) ⁶
35	Paramecium caudatum		101	Cytoplasm	5.0 ¹⁰	195	Peripheral cells	6.8(6.7-7.0) ⁶
36	Cytoplasm (aerobiosis)	6.8(6.7-6.9) ²	102	Nucleus	(7.2-7.5) ¹⁰	196	Central cells	6.4(6.4-6.5) ⁶
37	Digestive vacuole	4.0(4.0-7.6) ²	103	Unfertilized egg, cytoplasm	6.6(6.5-6.7) ¹	197	Kupffer cells	6.8(6.7-7.0) ⁶
38	Trichomonas vaginalis		104	Vacuole	5.0 ²	198	Ovary, eggs	7.8(7.5-7.8) ⁶
39	Cytoplasm	(5.5-6.8) ²	105	Fragarium elegans	(5.6-6.0) ¹⁰	199	Follicular cells	7.1(7.0-7.3) ⁶
40	Vorticella spp		106	Tissue	4.7 ¹⁰		Stromal cells	6.8(6.7-6.9) ⁶
41	Digestive vacuole	4.5(4.5-7.0) ²		Styelopsis spp		Plants		
42	Resting	5.0 ²	107	Cytoplasm	6.4(6.1-6.8) ¹¹	200	Brucella abortus	(7.2-7.6) ²
43	After contracting	3.5 ²	108	Fundulus heteroclitus	(6.6-6.8) ¹¹	201	Eberthella typhi	(7.2-7.6) ²
PORIFERA			109	Cytoplasm		202	Escherichia coli	(7.2-7.6) ²
44	Apysiniidae spp			PISCES		203	Klebsiella pneumoniae	(7.2-7.6) ²
45	Body substance	<6.0 ^{4, 8}	110	Fundulus heteroclitus		204	Saccharomyces cerevisiae	(6.1-6.3) ²
46	Cortex	8.0 ^{4, 8}	111	Cytoplasm	6.4(6.1-6.8) ¹¹	205	Staphylococcus spp	(6.1-6.3) ²
47	Choanosome	<7.0 ^{4, 8}	112	Striated muscle cells		206	Streptococcus spp	(6.1-6.3) ²
48	Mellita sexiesperforata			AMPHIBIA		THALLOPHYTA (Algae)		
49	Integument	7.5 ^{4, 8}	113	Rana esculenta		207	Laminaria digitata	
COELENTERATA				Histiocytes, cytoplasm	(6.0-7.2) ^{2, 12}	208	Stipe, outer cortex, mature	(4.8-5.3) ¹⁶
50	Aglantha digitalis, medusa			R. pipiens		209	Young	5.9 ¹⁶
51	Umbrella epithelium		110	Muscle fibers (in NaCl)	6.0 ¹	210	Stipe, inner cortex	(6.4-6.8) ¹⁶
52	Clytia johnstoni, medusa		111	(in NaHCO ₃)	8.4 ¹	211	Medulla, mature	(4.8-5.2) ¹⁶
53	Tissue	6.6 ²	112	R. temporaria		212	Young	(5.9-6.2) ¹⁶
54	Hydra fusca		113	Unfertilized egg, cytoplasm	6.0 ¹⁰		Nitella clavata	
55	Cortical protoplasm	(7.5-7.6) ⁶		Ovarian egg cell tissue	7.2 ¹¹	213	Cytoplasm	(5.0-6.2) ^{2, 11}
56	Inner protoplasm	6.8(6.7-7.0) ⁶		Fertilized egg, cytoplasm	8.5 ¹¹	THALLOPHYTA (Fungi)		
57	Nucleus	<6.8 ⁶		Salamander spp			Agaricus campestri	
58	Nematocyst cell, cytoplasm	7.1(7.0-7.2) ⁶		Muscle fibers	6.6 ¹¹		Stipe, pileus and hymeneal layers	5.9 ¹⁶
59	Pigment cell, cytoplasm	(7.4-7.6) ⁶						

43	Digestive cell, 3 day fast	7.2 ⁶		Triton marmoratus			THALLOPHYTA (Fungi) (concluded)	
44	After ingestion	<6.1 ⁶	114	Unfertilized egg, cytoplasm	7.2(7.2-7.3) ²	214	Amanita muscaria	
	Sagartia parasitica			T. taeniatus			Stipe, pileus and hymeneal layers	6.2 ¹⁶
45	Tissue	(5.6-6.0) ⁹	115	Outer cells, blastula	(7.6-7.8) ¹¹	215	Coprinus atramentarius	
	Sertularia pumila		116	Embryonic yolk	(6.9-7.0) ¹¹		Stipe	6.2 ¹⁶
46	Tissue	5.2 ⁹		AVES		216	Hypophoma fasciculare	
47	Tiara pileata, medusa	(6.2-6.4) ²	117	Pigeon (Columba spp)	(5.5-5.9) ¹¹		Stipe	(4.8-5.2) ¹⁶
48	Mantle canal and tentacle		118	Flight muscle tissue	(6.1-6.8) ¹³		BRYOPHYTA	
	Umbrella	7.2 ²	119		(5.5-6.1) ¹¹	217	Polytrichum commune	
	ROTIFERA		120	Leg muscle tissue	(6.7-7.4) ¹³	218	Epidermal walls	<3.4 ¹⁶
49	Roussette spp			MAMMALIA			Cortex	(4.0-4.4) ¹⁶
	Cytoplasm	(5.6-6.0) ¹⁰		Cat (Felis catus)			PTERIDOPHYTA	
	ECHINODERMATA			Alimentary canal		219	Dryopteris filix mas	
50	Arbacia equituberculata		121	Stomach, parietal cells	(6.9-7.0) ⁶		Rachis and rhizome	(4.8-5.2) ¹⁶
	Cytoplasm	(5.0-5.2) ¹¹	122	Chief cells	(6.4-6.5) ⁶	220	Equisetum maximum	
51	A. punctulata		123	Duodenum	(6.8-7.0) ⁶	221	Rhizome, endodermis	(4.8-5.2) ¹⁶
	Unfertilized egg, cytoplasm	6.8(6.6-7.0) ¹	124	Jejunum	(7.2-7.3) ⁶		Phloem	5.9 ¹⁶
52	Pigment cells	5.3(5.0-5.6) ⁵	125	Ileum	(7.4-7.6) ⁶		SPERMATOPHYTA (Gymnosperma)	
	Asterias glacialis		126	Large intestine	(7.4-7.6) ⁶		Pine, Austrian (Pinus nigra austriaca)	
53	Unfertilized egg, cytoplasm	7.2 ¹	127	Cartilage, bronchial	(6.6-6.9) ⁶	222	Stem, epidermal and xylem walls	<3.4 ¹⁶
54	Oocyte, cytoplasm	7.2(7.0-7.4) ¹	128	Kidney tissue	7.0 ¹¹	223	Mesophyll	(4.8-5.2) ¹⁶
	A. rubens		129	Tubules	(6.7-7.0) ⁶		SPERMATOPHYTA (Angiosperma)	
55	Unfertilized egg, cytoplasm	6.7(6.6-6.8) ¹	130	Reticular cells	6.5(6.4-6.6) ⁶	224	Broad bean (Vicia faba)	
56	Nucleus	7.5(7.4-7.6) ¹	131	Liver tissue	(6.8-7.0) ¹³	225	Stem, epidermis	5.6 ¹⁶
57	Fertilized egg, cytoplasm	6.7(6.5-6.9) ¹	132	Peripheral cells	(7.3-7.5) ⁶	226	Cortex, outer	(4.8-5.9) ¹⁶
58	Cortical protoplasm	5.0 ²	133	Central cells	(6.7-7.0) ⁶	227	Pericycle	(4.8-5.2) ¹⁶
59	Inner protoplasm	7.6 ²	134	Kupffer cells	(6.4-6.5) ¹¹	228	Pith	(5.6-5.9) ¹⁶
	Echinocardium cordatum		135	Muscle, cardiac	(6.8-7.0) ¹¹	229	Roots, exodermis	(4.8-5.2) ¹⁶
60	Unfertilized egg, cytoplasm	6.6 ¹	136	Ovary, eggs	(7.5-7.8) ⁶	230	Phloem	(4.0-5.2) ¹⁶
	Ophiura lacertosa		137	Follicular cells	7.1(7.0-7.3) ⁶	231	Cambium	(4.8-5.2) ¹⁶
61	Unfertilized egg, cytoplasm	6.7(6.6-6.8) ¹	138	Stromal cells	6.8(6.7-6.9) ⁶	232	Leaves, epidermis	(4.8-5.6) ¹⁶
	Paracentrotus lividus		139	Pancreas, parenchyma	(7.2-7.4) ⁶	233	Chlorenchyma	(4.8-5.9) ¹⁶
62	Cytoplasm	7.2(7.0-7.4) ¹	140	Islet cells	(6.6-6.9) ⁶	234	Flowers, epidermis	(4.8-5.2) ¹⁶
63	Unfertilized egg, cytoplasm	6.6 ¹	141	Skin, surface epithelium	(7.3-7.5) ⁶	235	Anthems	(5.6-5.9) ¹⁶
64	Nucleus	7.2 ¹	142	Basal epithelium	(6.8-6.9) ⁶	236	Pollen	(4.8-5.6) ¹⁶
	Psammecinus miliaris		143	Horny epithelium	6.2 ⁶		Seeds, plumule	(4.8-5.2) ¹⁶
65	Cytoplasm	5.2 ¹⁰	144	Uterus, horn	6.6 ¹⁴	237	Potato (Solanum tuberosum)	
	ANNELIDA			Dog (Canis familiaris)	6.9(6.8-7.0) ¹⁵	238	Stems, epidermis	(4.8-5.2) ¹⁶
66	Arenicola clapedii		145	Cardiac muscle	(6.4-6.7) ¹¹	239	Cortex, outer	(4.8-5.9) ¹⁶
	Nucleus	(7.2-7.5) ¹⁰	146	Striated muscle		240	Pericycle	5.6 ¹⁶
67	Lumbricus spp		147	Hamster (Cricetus spp)	7.4 ⁶	241	Roots, piliferous layer	5.6 ¹⁶
68	Ectoderm, central protoplasm	7.3 ⁶	148	Testes, cortical protoplasm	6.8 ⁶	242	Phloem	5.6 ¹⁶
	Muscle cells	6.7 ⁶	149	Central protoplasm	(6.4-7.4) ⁶	243	Cambium	5.9 ¹⁶
	Nereis limbata		150	Spermatozooids	6.7(6.6-6.8) ⁶	244	Tuber, sap	(4.8-5.2) ¹⁶
69	Cytoplasm	(5.6-6.0) ¹⁰		Interstitial cells		245	Cytoplasm	5.9 ¹⁶
	Platydelta soleae			Guinea pig (Cavia porcellus)		246	Leaves, epidermis	5.6 ¹⁶
70	Salivary gland tissue	(5.6-6.0) ¹⁰	151	Alimentary canal			Chlorenchyma	5.9 ¹⁶
71	Clitellum tissue	(5.6-6.0) ¹⁰	152	Cartilage, chondrocytes	(6.6-6.8) ⁶	247	Sunflower (Helianthus annuus)	
	Sabellaria alveolata		153	Stomach, parietal cells	(6.9-7.1) ⁶	248	Stems, epidermis	(4.0-4.4) ¹⁶
72	Cytoplasm	5.0 ¹⁰	154	Chief cells	(6.5-6.6) ⁶	249	Cortex, outer	(4.8-5.8) ¹⁶
73	Nucleus	6.0 ¹⁰	155	Duodenum	(6.8-7.0) ⁶	250	Pericycle	(4.8-5.8) ¹⁶
74	Unfertilized egg, cytoplasm	6.6(6.5-6.7) ¹	156	Jejunum	(7.2-7.3) ⁶	251	Roots, exodermis	(4.0-5.2) ¹⁶
	Spirographis spp		157	Ileum	(7.4-7.6) ⁶	252	Phloem	(4.8-5.2) ¹⁶
75	Cytoplasm	6.0 ¹⁰	158	Large intestine	(7.4-7.6) ⁶	253	Cambium	(4.8-5.2) ¹⁶
76	Chordoid cells	7.2 ²	159	Kidney, tubules	(6.8-7.0) ⁶	254	Leaves, epidermis	(4.0-4.4) ¹⁶
77	Cytoplasm, tentacles	7.2 ²	160	Liver, total tissue	6.9(6.8-7.0) ¹³	255	Chlorenchyma	(4.8-5.8) ¹⁶
78	Vacuole	6.6 ²	161	Peripheral cells	7.3(7.1-7.5) ⁶	256	Flowers, epidermis	<3.4-4.4 ¹⁶
	MOLLUSCA		162	Central cells	6.8(6.7-7.0) ⁶	257	Anthems	(5.6-5.9) ¹⁶
79	Anodonta cygnea		163	Kupffer cells	6.4 ⁶	258	Pollen	(4.8-5.2) ¹⁶
	Liver cells	6.8 ¹¹	164	Ovary, eggs	(7.5-7.8) ⁶		Seeds, plumule	(4.8-5.2) ¹⁶
	Aplysia limacina			Follicular cells	7.1(7.0-7.3) ⁶			
80	Cytoplasm	(7.0-7.8) ¹⁰						

1/ Microinjection of liquid indicators. 2/ Vital staining. 3/ Micropipette method. 4/ Natural indicators. 5/ Spectrophotometric determination. 6/ Microinjection of solid indicator particles. 7/ Tissue culture method. 8/ Gas cell apparatus. 9/ Data on method not available. 10/ Crushed cells in solution. 11/ Electrometric methods. 12/ Ameboid movement with phagocytosis of India ink. 13/ Haas colorimetric method. 14/ Perfusion of tissues, buffering capacity. 15/ Tissue brei. 16/ Range indicator method of Small.

55. VERTEBRATE TISSUES AND ORGANS: CHEMICAL COMPOSITION

The subject matter of this table is probably the most controversial, and the values therein the most widely variable, of any table in the Handbook. Data from many contributors and hundreds of literature references have gone into its make-up, and each value or range may represent a "reconciliation" of several divergent values obtained by almost as many divergent analytical methods from a number of domestic and foreign laboratories. Therefore, it has been almost impossible to devise a system for presenting an accurate mean value or "95% range" for any component listed. Some of the values are means, some single observations, others ranges of means, and still others ranges of extremes. Consequently the user of this table is warned that these values are to be considered only as "yardsticks," and are not subject to statistical manipulation or conclusive interpretation.

Part I: NERVE TISSUE Section 1: Man, Cat, Cattle, Dog, Rabbit, Rat

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight; PN = peripheral nerve.

Component	Man				Cat			Cattle			Dog			Rabbit		Rat	
	Whole Brain	Spinal Cord	Gray Matter ¹	White Matter ¹	Whole Brain	Gray Matter ¹	PN	Whole Brain	Gray Matter ¹	White Matter ¹	Whole Brain	Gray Matter ¹	White Matter ¹	Whole Brain	Spinal Cord	Whole Brain	Gray Matter ¹
1 Water, %	70-85	65-75	80-85	60-75	80			70-85			75	80	65-75	75-80	68	80	80
2 Ash, %	1.5	1.4	0.92	0.7-1.8	1.0			1.15 PN	1.5	2.4		1.5	2.7	1.5-1.8	1.7	1.4	
3 Calcium	7-15	18	10.4	14	4-17			12-18	13	16	2-26			8.6-12	5.2-16	4.7-55*	45*PN
4 Chlorine	110-160	150	115-215	130-160	140		215	110-185	125	175	125-130	155	125	130-165	145	160-220	120
5 Copper	0.04-0.53		2.4-9.9* ²	1.8-8.2* ²				0.18PN									
6 Iron	5.2-8.3		30	21				4.4-8.2	5	7.4						4-9	
7 Magnesium	19-40	40	20	25				65*			13.0-13.5					14	75*PN
8 Manganese			0.16	0.2				1.3-10 PN						35			
9 Nitrogen, total, %	1.6-1.8 ³	1.6	1.6-1.7	1.7-1.8	1.7		2.5	2.1 PN	1.7	1.7	1.9	1.5-1.7	1.4-1.8	1.7		2.1	1.8
10 Acid-soluble, %			0.26 ²	0.33			0.14					0.14	0.13			0.13-0.18	
11 Amino					53		0.1					0.1	0.08			0.04	
12 Phosphorus, total	215-415	550	205-245	365-440	300		380-435	245-440	255	435	730 ⁴	250-260	440-470	330 PN		195-305	1090*PN
13 Inorganic	32-50 ²		40	45-64	14-46		25	16 PN			7-9 ⁵	55	50			13-20	16 PN
14 Acid-soluble	115-165 ²		140	240	67		51				65 ⁵	80	65-75			55-75	
15 Potassium	285-400	360	230-345	230-380	345			215-345			360-375	375	340	360-400	375-400	235-450	400
16 Sodium	110-300	200	120-205	160-225	120			75-165			115	150	120	120-145	145	110	115
17 Sulfur	207	85	55-75	90-150													
18 Zinc	0.7							0.22 PN								1.5	
19 Protein, total, %	10-11	9	7.3-8.2	7.7-9.2	9-11	10	10.9-12.3	10.3	10	8	12	8	8-13	8-9		11	
20 Neurokeratin, %		0.6 PN	0.31	1.12				0.48									
21 Lipid, total, %	13.3	2.3-18.5PN	5.1-5.3	16.3-17.8	6		18-20	12			11-13			10.2-12.4		23-45	
22 Phospholipid, total, %	25*	22-30*	3.1-4.3	6.2-11.3	4.3-5.7	4.0-4.5	5.9-7.3	24-30*			4-5	3.9-4.2	8.3-8.5	5.0-5.6	10.6	4.7-5.8 ⁶	4.5
23 Cephalin, %	14.8-26.0*	0.4-1.2 PN	1.8-2.2	2.7-3.7	2.1-2.7	1.9	1.7-3.0	13-16*					2.8			1.5-2.4	
24 Lecithin, %	4.6-4.9*	0.3-0.6 PN	0.6-1.2	0.9-1.7	1.2-1.3	1.3	1.5 ⁴	6.6-7.5*					1.4	1.8		0.9-1.8	
25 Sphingomyelin, %	4.5-6.8*	2.6-2.8*	0.3-0.6	1.8-2.6	0.9	0.7	3.1 ⁴	5*			4		0.9	3.7		0.7-1.6	
26 Sulfolipid, %			1.2														
27 Cerebroside, %	1.2-2.4	5-6*	0.6-1.2	4.1-4.8	1.9-2.5	1.1-1.9	1.5-2.9	11.6-12.5*	1.2	5.3	3 PN	1.5	6.9-7.4	2.4-2.9	5.9	1.1-2	1.2
28 Cholesterol, %	2.6-4.4	0.53	0.8-1.1	3.8-4.2	2.2-2.8	1.2-1.3	3.2-3.4	10-11*					2.2	5.9		0.2-0.6	0.9
29 Nucleic acid, DNA	80	3.1-5.3 ^{2,7}		4-9.8 ⁷	5.8 ⁷		4.3-5.8 ⁷				80	5 ⁷	6 ⁷	95		140	
30 RNA	105-140			12-26 ⁷	7.6 ⁷		3.6-3.9 ⁷				95	10 ⁷	5 ⁷	215		160	

/1/ Unspecified. /2/ Cortex. /3/ Infant. /4/ Spinal cord. /5/ % of total P. /6/ Plasmalogens 320-340 mg/100 g fresh tissue. /7/ As phosphorus.

Section 2: Other Animals

Values are mg/100 g fresh WHOLE BRAIN tissue unless otherwise indicated. * = dry weight; AX = axoplasm; GM = grey matter (unspecified); PN = peripheral nerve; SC = spinal cord.

Component	Beaver PN	Guinea Pig	Horse PN	Monkey	Mouse	Sheep	Chicken	Duck	Gull	Pigeon	Tortoise	Frog	Carp	Perch, Yellow	Shark, Sand	Invertebrates	
																Value	Organism
1 Water, %		78	71	78	79	84GM	79	78	81	79	83	84 ¹	81	82	81		
2 Ash, %			1.0			1.4GM						1.6	2.2				
3 Calcium		4-11				10.8						14PN				5	Crab
4 Chlorine			230									130PN		150		355AX	Squid
5 Nitrogen, total, %					2.2		1.1-1.2	1.7			1.2	1.5	1.3				
6 Phosphorus, total		300	250	390PN	320							330PN				78AX	Squid
7 Potassium			130-180		370							185PN				420PN	Cockroach
8 Sodium			450		100							145PN				140PN	Cockroach
9 Sulfur			40		260												
10 Protein, total, %		8.7-9.2		9.5SC	10.4		7.2-7.6	10.7		45-50*	8	6.7-7.5PN	8			90-95*	Bee
11 Lipid, total, %		9.8-10.5				10.7	9.2-10.2	9.4		4.2-5.4	7.2		9.2			35-45*	Bee
12 Phospholipid	5.9	4.2-4.9	2.8	8.2PN	4.5		4.2	3.7				3 ¹	4	4.2	3.7	16-18*	Bee
13 Cephalin, %		2.8							2.3	2.4		1.2 ¹		1.7	2.8		
14 Lecithin, %		1.4							1.3	1.3		1.3 ²		1.5	1.3	0.15 ³ AX	Squid
15 Sphingomyelin, %		0.9							0.4	0.7		0.4 ²		0.9	0.6	1-2*	Bee
16 Cerebroside, %	1.3	2.2-2.4							1.4	1.3		1.2 ¹	0.7	0.3	1.2		
17 Cholesterol, %	3.2	1.7-1.9				1.0	1.6-2	1.8	1.3	1.4-2		0.8 ¹	1.1	1.3	1.1	0.8-1.6*	Bee
18 Nucleic acid, DNA		110				80		95					205				
19 RNA		255				165		160					265				

/1/ Leopard frog. /2/ Turtle. /3/ Cephalin + lecithin, %.

Part II: LUNG

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight; FF = fat-free.

Component	Man	Cattle	Dog	Rabbit	Rat	Component	Man	Cattle	Dog	Rabbit	Rat
1 Water, %	78-80	80	78	80-82	77-85	12 Potassium	150		155-250		
2 Ash, %	1.1			1		13 Silicon ¹	20-40				
3 Bromine	0.3-0.7	0.35				14 Sodium	240		155-210	165	
4 Calcium	17					15 Zinc	4-15*				1.9
5 Chlorine	260		195-255	230	215-430	16 Protein, %	14.9-16.7				
6 Chromium, µg/100 g	13					17 Phospholipid, %	3.4	11.5*FF	14.2*FF	1.3 ²	6.6
7 Copper	0.5-1.4*					18 Cephalin, %	1.4-2.6*				0.8
8 Iron	2-22			12.4		19 Lecithin, %	3.8-4*	3.3*			1.8
9 Magnesium	7	62*				20 Sphingomyelin, %	0.9-1.5*	2.3*			0.45
10 Phosphorus, total	95-120					21 Cholesterol, %	2.2*	2.2*FF			0.4
11 Nucleic acid	250*		265*		375*	22 Carbohydrate, %	0.4*				

/1/ As total silica. /2/ Total lipid.

Part III: HEART

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight; FF = fat-free.

Component	Man				Cat	Cattle	Dog	Guinea Pig	Rabbit	Rat	Swine	Chicken
	Whole Heart	Left Ventricle	Right Ventricle	Auricles								
1 Water, %	71-80	76-85	78-83	80-84	79-81	70-77	76-81	76	76-80	76-83	80	70
2 Ash, %	1.1	3.5-5.6*				0.92			1.0			
3 Aluminum	0.1-0.3						0.17			0.16	0.6	
4 Bromine	0.07-0.3						0.18		0.07			
5 Calcium		4.9-10.4	4.4-15.1			10	9.3	6.8	67*	3-20		
6 Chlorine	125-185	105-170	125-185	120-170	120-145	100 ¹	110-135		125-180	85-110		
7 Chromium	0.01											
8 Copper	0.34	0.2-0.5			1.4*	0.76		2.1*	2.2*	0.2	1.5	1.5*
9 Fluorine	0.46											
10 Iron	35*	4-21				4.2-6.2	0.27 ²		12.4	5-11		
11 Lead	0.05-0.08											
12 Magnesium	17.4	13-25	13-30			110-125	21-23 ²	9	51*	18-26		
13 Manganese	0.02-0.05					0.03	0.21	0.02	0.02	0.06	0.2	0.07*
14 Phosphorus		145-235	125-185		207	160-235	217		175-240	240		
15 Potassium	275	245-355	190-240	95-220	300-365	255-355 ²	285-340	280	275	320-340	320	
16 Silicon	35-120*											
17 Sodium		85-140	80-165	75-170	95-110	80-135 ²	88	135	120-135	85-95	95	
18 Zinc	7-14						2		1.1-6.1			
19 Protein, %	16				17.6	16.5	18 ²					
20 Collagen, %		0.6-1.4	1.2-2.0	3.4-4.0	1.2	1.9 ²	2.7 ²	0.7-1.2	2* ²	0.8	2.2* ²	
21 Elastin, %					0.15	0				0.14		
22 Lipid, %	8.3	0.2-0.9	0.5-2.4			3.1-19.5			4 ³	0.4-2.4		
23 Phospholipid, %	6.3-7.5*FF					7.4-11.8*	11.7*			5-8*		1.5 ²
24 Choline-, %	6*FF					4.9*	5.3*			2*		
25 Cephalin, %	1.4-2.8*					5.3*				0.84		
26 Lecithin, %	3.3-5.7*					4*				2		
27 Sphingomyelin, %	0.2-0.5*					0.5*				0.14		
28 Cerebroside, %						2*				1.4*		
29 Cholesterol, total, %					0.44* ²	0.4* ⁴	0.6*	0.2	0.6*	0.4-0.6*		0.27
30 Glycogen					475		440-495	240	335-640	240-680		
31 Creatine	115-265	140-265	100-195		220-335		210-325		210-245	160-260		180*

/1/ Auricle. /2/ Ventricle. /3/ Total fat. /4/ Free cholesterol.

55. VERTEBRATE TISSUES AND ORGANS: CHEMICAL COMPOSITION (Continued)

Part IV: MUSCLE

Section 1: Man, Cat, Dog, Rabbit, Rat

Values are mg/100 g fresh muscle (type unspecified), unless otherwise indicated. * = dry weight; FF = fat-free.

Component	Man	Cat	Cattle	Dog	Rabbit	Rat	Component	Man	Cat	Cattle	Dog	Rabbit	Rat
1 Water, %	74-84 ¹	77	70	73-76	68-80	76	18 Zinc	12-30*				0.9-1.4*	
2 Ash, %	1.1		0.8-1		1.0-1.4	1.3	19 Protein, %	18.5	18.2	19.3	21 ¹	19-25	21 ¹
3 Bicarbonate	98 ¹	70 ¹					20 Collagen, %			2.1*FF			0.65-2.0 ⁴
4 Bromine	0.3-0.6						21 Elastin, %						0.07-0.37 ⁴
5 Calcium	6.5-7.4	3.5	11	3.3	18	6.3 ¹	22 ATP ⁵				40-60 ¹	270-420 ¹	330 ¹
6 Chlorine	45-110	55	55	50-75	50-100	40-140	23 Anserine		90 ¹		105 ¹	370 ¹	505 ¹
7 Chromium, µg/100 g	0.2						24 Carnosine		250 ¹		29 ¹	100 ¹	46 ¹
8 Copper	0.64-1.3*						25 Citric acid				1.1 ⁶	2.5	
9 Iron	25.3		2.8-3.7		2.7	1.9	26 Lactate	80-120 ¹	15-20 ¹		30-60 ¹	39 ¹	9-29 ¹
10 Magnesium	18.4-21.5	28.2 ¹	32	44 ¹	29	27 ¹	27 Lipid, total, %	7.6	2.5	10-14	14	1.2-7.6	3.7-10.6
11 Manganese, µg/100 g	8.2-10						28 Fat, neutral, %			6-12*		7	0.75-1.8
12 Nitrogen, %	3			3.5 ²		1.24 ³	29 Phospholipid, %			3.7*	5.8*		4.4-8.6*
13 Phosphorus, total	150-200	205	210	185-205 ¹	245	185-250	30 Choline phospholipid, %			2.3*	2.9*		2.1*
14 Acid-soluble	175	165 ¹		115-140 ¹	150-185 ¹	160-185	31 Cholesterol, %	0.2*	0.2*	0.24*	0.3*	0.05	0.07
15 as PO ₄	85-195 ¹			75-120 ¹	22-35 ¹	75-105 ¹	32 Hexose monophosphate		35-45 ¹		35-55 ¹	140-185	260 ¹
16 Potassium	300-435	350	260-525	320 ¹	415	385-475	33 Glycogen	1.3-2.2 ¹	0.3-1		0.5-1.9 ¹	140	270-320
17 Sodium	65-105	55	45-165	74	40-55	40-60	34 Creatine	440 ¹	380-440		370	380-440	440

/1/ Skeletal muscle. /2/ Sacrospinalis muscle. /3/ Collagen. /4/ Thigh muscle. /5/ Adenosine triphosphate. /6/ Abdominal muscle.

Section 2: Other Animals

Values are mg/100 g fresh muscle (type unspecified), unless otherwise indicated. * = dry weight; FF = fat-free.

Component	Guinea Pig	Sheep	Swine	Chicken	Pigeon	Snake ¹	Turtle	Frog	Cod	Eel	Salmon	Invertebrates	
												Value	Organism
1 Water, %	75	52-64	65		74 ¹	75-78	79	79-82 ¹	72-83	54-59	64-70	78-84	Lobster
2 Ash, %		0.85	1				1			1.2 ²	1.2 ³	1.6	Lobster
3 Calcium		10-20				15-30		8-21 ¹	25	9-16	17	107	Crayfish
4 Chlorine		70				35-125		40-65 ¹	215	50-110	190		
5 Magnesium		33	100* ⁴	110* ⁴		4.6-10.2		24-65 ¹	22	14.4	32	21	Crayfish
6 Phosphorus		185-210			260 ^{1,5}	175-215		105-185 ¹	220-240	190-200	230	140-180	Cockle
7 Potassium		205-295				85-140		305-350 ¹	350	190-245	340	400	Crayfish
8 Sodium		80-140				110-145		55 ¹	140	50-95	120	105	Crayfish
9 Protein, %	19-21 ⁶	17.1	19				14.5		25	13.5-15.3	25	14.2-20.1	Lobster
10 Lipid, total, %		17.5-32	8	7-12.7* ⁷			17.4*	2-11	9.5*	26-30	18.3*	8.1*	Shrimp
11 Phospholipid, %		4.7	3.1*	2.7-4.4* ⁷	3-5* ⁸		5.3*	7.1*	4.3*		4.4*	4*	Shrimp
12 Cholesterol, %	0.1	0.26*	0.06	0.7 ⁹	0.11		0.7	0.04	0.05		0.06	0.7 ¹⁰	Shrimp
13 Glycogen	290-910 ⁶				670					4-95 ²	24-65 ³	2600-4200	Oyster
14 Creatine	280-440			65 ¹¹	36 ¹¹	180-445		80 ¹					

/1/ Skeletal muscle. /2/ Flatfish. /3/ Shark. /4/ Gluteus muscle. /5/ As phosphate. /6/ Gastrocnemius muscle. /7/ "Dark and white" meat. /8/ Pectoralis major muscle. /9/ Thigh muscle. /10/ Free cholesterol. /11/ Breast muscle.

Part V: GONADS AND SEX ORGANS

Values are per cent fresh tissue, unless otherwise indicated. * = dry weight; FF = fat-free.

Component	Man				Cattle		Dog	Guinea Pig	Rabbit	Rat				Swine
	Ovary	Uterus	Testis	Prostate	Testis	Testis	Testis	Mammary	Mammary	Ovary	Uterus	Testis	Prostate	Prostate
1 Water	80.5 FF		84	82.5	86	83-92 FF	80	38 ¹	73-75	82-89 FF	87.3 FF			
2 Solids, total				16-20	21.8 ²		10.3*	12.5 FF	23.5-25			18-26 ³		15.6
3 Ash				0.83				0.3	1.1-1.6			0.85-1.2 ³		
4 Bromine, mg/100 g		0.3-0.8	0.26	0.28	0.27						0.9-1.1	1-1.6		
5 Chlorine, mg/100 g ⁴		210												
6 Potassium, mg/100 g ⁴		290				205-225 FF		135 ⁵			140-150	330		
7 Uranium, µg/100 g	3.3			4.0		315-390 FF					240-260			
8 Zinc, mg/100 g			6.8-16.3*	9.4-25	4.1 ²	1.7		1.4-16.7 ⁶	1.9-2.3	1.1-1.8		2.7-3.1	13-25 ⁷	3.8
9 Lipid, total				1.2	1.6			17-36 ²				1.1		
10 Fatty acids				0.12			9.7	76.5* ⁹						
11 Cholesterol, total				0.22-0.8			0.26 ⁶	89.3 ^{9,10}	1.2 ¹¹			0.8* ¹²		
12 Citric acid					14.3-23.2 ¹³		80-100	52-62 ²					70-120 ³	38

/1/ In lactation, 55-75% H₂O. /2/ Prostate. /3/ Ventral. /4/ Of tissue water. /5/ Ovary. /6/ Testis. /7/ Posterior. /8/ Early lactation. /9/ Calcium salts. /10/ Per 100 g dry fat. /11/ Immature ovary. /12/ Free cholesterol. /13/ Mammary.

Part VI: TEETH

Section 1: Man

Values are per cent dry tissue, unless otherwise indicated. FW = fresh tissue; TA = tissue ashed.

Component	Whole Teeth	Enamel	Dentine	Pulp	Component	Whole Teeth	Enamel	Dentine	Pulp	Component	Whole Teeth	Enamel	Dentine	Pulp
1 Water	4-14.3 FW	0.5-6.6 FW ¹	4.2-16.7 FW ¹		8 Magnesium	0-1.8 FW	0.16-1.16 TA	0.8-1.6 TA		15 Carbonate ³	3-5 TA	2.6-3.7 TA	4.3-5.1 TA	
2 Ash	68-80	95.4	71.1	21.2	9 Nitrogen				10.1	16 Protein, total	18 FW			60-65 FW
3 Calcium	27-37 TA	35-39	27.8	5.7	10 Phosphorus	16.5-19.0 TA	16.8-18.5 TA	16.5-19.0 TA	3.5	17 Insoluble		0.2-0.5 FW	15.5 FW	
4 Chlorine		0.3	0		11 Potassium		0.05 ²	0.07		18 Fat, total				0.9 FW
5 Copper, mg/100 g	0.52 TA				12 Silicon, mg/100 g	3.0				19 Phospholipid				0.7 FW
6 Fluorine, mg/100 g	4.5-28.7 FW	0-25	13.3-32 FW		13 Sodium		0.25	0.2		20 Cholesterol, mg/100 g				0.11 FW
7 Lead, mg/100 g	5.1 TA				14 Zinc, mg/100 g	0.3 TA	15.2-25 TA	14.8-26 TA		21 Citric acid	0.7	0.09	0.8	

/1/ Deciduous. /2/ Or less. /3/ As CO₂.

Section 2: Other Mammals

Values are per cent dry tissue, unless otherwise indicated. FW = fresh tissue; FF = fat-free tissue; TA = tissue ashed.

Component	Dog	Elephant	Guinea Pig	Hamster		Hare	Horse	Monkey	Rabbit	Rat		Swine
	Dentine	Dentine ¹	Whole Teeth ²	Enamel ²	Dentine ²	Whole Teeth ²	Dentine	Dentine	Whole Teeth ²	Enamel ²	Dentine ²	Pulp
1 Ash				85-92	74-76							3.8 FW
2 Calcium	37.6 TA	32.9 TA	35-36 TA	25-34	19-24	36 TA	37.1 TA	37 TA	35-36 TA	33-35 FF	27-28 FF	0.23 FF
3 Fluorine, mg/100 g	28-41 FW ³											4.2 FW
4 Magnesium		4.1 TA	1.7 1.9 TA	0.7-1.3	0.8-1.5	1.8-2.3 TA	1.9 TA		1.5-2.5 TA	0.25-0.44 FF	0.37-1.5 FF	0.07 FW
5 Phosphorus	19.6 TA	19.6 TA	20 TA	17-18	14-16	19-20	19.2 TA	20 TA	20 TA		15.9-17.4 FF	0.23 FW

/1/ Tusk. /2/ Incisors and molars. /3/ Whole teeth.

Part VII: BONE

Section 1: Man, Cattle, Dog, Horse, Rabbit, Rat

Values are per cent fresh tissue (compact bone) unless otherwise indicated. * = dry weight; FF = fat-free tissue; Unspec. = bone type not specified.

Component	Man				Cattle		Dog		Horse		Rabbit		Rat	
	Bone Type				Bone Type	Value	Bone Type	Value	Bone Type	Value*FF	Bone Type	Value	Bone Type	Value
	Unspec.	Epiphysis	Femur	Rib										
1 Water	30-44	84 ¹		81	Femur	75*FF	Unspec.	40-59	Femur	70.2	Unspec.	39-58	Femur	34.6
2 Ash	22.1		66.8*FF		Unspec.	25-30	Unspec.	25-30	Femur	72*FF	Femur	72*FF	Unspec.	34-40
3 Calcium			25.6*FF	25.6*FF	Unspec.	25.8*	Femur	25.5*FF	Femur	26.2	Femur & tibia	27-31*FF	Femur & tibia	27-29*FF
4 Carbonate, as CO ₃			4.0*FF		Unspec.	5.8*FF	Femur	4.5*FF	Femur	5.7	Femur	5.7	Femur	5.2*FF
5 Chlorine	0.17								Femur	0.19 ²	Unspec.	0.18 ²	Unspec.	
6 Copper, mg/100 g	0.65*		0.2	0.37-4.8										
7 Fluorine, mg/100 g				61-310*FF	Rib	36-51*FF			Femur	100	Long bone	12-18*FF	Femur & tibia	10-29*FF
8 Iron, inorg., mg/100 g	10.3-16.1 ³			11.2-16.7							Unspec. ⁴	8.1		
9 Magnesium		0.015	0.39*FF	0.02	Femur ⁵	0.42-0.64*FF	Femur	0.44*FF	Femur	0.23			Femur	0.7*
10 Manganese, mg/100 g	0.3		0.2	0.2	Femur	0.05					Femur	0.7*	Unspec.	2.2
11 Nitrogen			4.2-4.6*FF	5.1*FF	Rib	4.25*	Femur	5.27*FF	Femur	5.4	Femur & tibia	2.9-3.5*FF	Femur & tibia	3.0-3.7*FF
12 Phosphorus	11.5*FF		12.3*FF		Unspec.	11.9*	Femur	11.9*FF	Femur	11.4	Unspec.	3.6-4.2	Femur & tibia	11.9-13.5*FF
13 Potassium	0.055	0.2		0.3					Femur	0.02				
14 Sodium	0.44*FF						Unspec.	0.44*FF	Femur	0.39				
15 Strontium	0.06-0.22 ⁶													
16 Fat					Femur	0.1*	Unspec. ⁷	13.0			Femur	0.1*	Unspec. ⁷	5-7
17 Citric acid	0.7-2.0*FF		1.4-1.9*FF	1.4-2.1*FF	Leg bones	0.27	Femur	1.0-1.3*FF			Tibia	0.72-0.83*	Tibia	0.3-0.42*

/1/ Cartilage. /2/ mg/100 g. /3/ Vertebrae. /4/ Compact and spongy (cancellous) bone. /5/ Femur head spongy bone. /6/ Tibia. /7/ Total lipid.

Section 2: Other Vertebrates

Values are per cent dry, fat-free tissue (compact bone), unless otherwise indicated. FW = fresh tissue.

Component	Cat		Ferret		Guinea Pig		Sheep		Turkey		Turtle		Frog	
	Bone Type	Value	Bone Type	Value	Bone Type	Value	Bone Type	Value	Bone Type	Value	Bone Type	Value	Bone Type	Value
1 Ash	Femur	67-70	Femur & tibia	26-31	Femur & tibia	28-31	Rib ¹	61-64	Femur	69.5	Femur	62.7	Femur	67.6
2 Calcium	Femur & tibia	26-29	Femur & tibia	26-31	Femur & tibia	28-31	Rib ¹	22.2-23.0	Femur	26.5	Femur	24.3	Femur	26.2
3 Carbonate, as CO ₂						5.0 ²	Femur	4.7	Femur	4.5	Femur	5.6 ²	Femur	4.7 ²
4 Magnesium							Femur	0.52-0.70	Femur	0.52	Femur	0.54	Femur	0.54
5 Nitrogen	Femur & tibia	3.4-4.6	Femur & tibia	3.3-4.5	Femur & tibia	2.7-3.1	Femur & tibia	2.9-3.5	Femur	4.9	Femur	5.9	Femur	5.2
6 Phosphorus	Femur & tibia	11.5-12.9	Femur & tibia	11.5-13.2			Rib	10.8	Femur	12.6	Femur	10.5	Femur	12.3
7 Citric acid	Rib	0.4-0.6 FW											Unspec.	0.29

/1/ Compact and spongy bone. /2/ Per cent of ash, calculated as CO₂.

55. VERTEBRATE TISSUES AND ORGANS: CHEMICAL COMPOSITION (Continued)

Part VIII: BONE MARROW

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight.

Component	Man			Cat	Cattle	Dog	Guinea Pig	Rabbit			Rat	Swine	Frog
	Sternum	Tibia	Unspec. ¹	Femur	Femur	Femur	Femur	Femur	Rib	Combined ²	Femur	Femur	Femur
1 Water, %	14.0			50	41.3	21.0	71	74	46-55	7-16	68	8.1	65
2 Ash, %	0.55												
3 Calcium	32.7	4.4-11.0											
4 Copper					0.35 ³					0.07-0.09 ³		2.2 ⁴	
5 Iron	30-55												
6 Phosphorus	18.3									2.4-3.6			
7 Protein, %				11.5	1.4	5.4	17.0	7.6			17.2	1.2	5.4
8 Fat, %			30-90	38.2			10.4	56			14.0		28.4
9 Sugar	65-275	11-55											

/1/ Unspecified origin of marrow. /2/ Radius + ulna + distal end of tibia. /3/ "Leg (long) bones." /4/ Rib.

Part IX: LIVER

Section 1: Man, Cattle, Rabbit, Rat

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight.

Component					Component				
Man					Man				
1 Water, %	73-77	69-71	70-76	69-72	17 Potassium	170-250	225-395	190-260	365-395
2 Ash, %	1.4	1.4	1.2-2.0	1.4-1.6	18 Silicon	5-20			
3 Arsenic	0.15				19 Sodium	120-150	53-345	75-140	305
4 Bromine	0.04-0.43	0.7			20 Zinc	5.4	3.4-8.4	22	3.0-3.2
5 Calcium	7.2-9.4	8.3	5-16	2.8-3.8	21 Protein, %	17.0	20.0		16.0-22
6 Chlorine	96-150		105-160	90-115	22 Collagen, %	0.5-1.5			0.23
7 Chromium, µg/100 g	0.6				23 Elastin, %	0.1-0.5			
8 Copper	1.5-13	8.5	3.0 ¹	2.1-20.4*	24 Lipid, total, %		6-7.4		5.0
9 Iron, total	13.4	12.1	18.5	3.0-22	25 Fat, total, %		7.0	0.23	1.1-29
10 Inorganic	3.0-16.2		8.2-10.3	7.0-18.2	26 Phospholipid, %	9-11*	17.3-25.1*		2.2-2.7
11 Lead	0.2				27 Cephalin, %	3.0-5.4*	5.0*		0.8-1.4
12 Magnesium	17	60-75*	13.4	19	28 Lecithin, %	3.3-6.0*	8.0*		1.1-3.1
13 Manganese	0.08		0.2		29 Sphingomyelin, %	0.3-0.43*	0.8*		0.2-0.4
14 Phosphorus, total	180-240	375		280-375	30 Cholesterol, total, %	0.2-0.4	0.32	0.05	0.25-0.3
15 DNA ²	19	34		20-37	31 Carbohydrate, %		4.0		2.3
16 RNA ³	37	70		55-120	32 Ascorbic acid	5.0			

/1/ In the newborn. /2/ Desoxyribonucleic acid P. /3/ Ribonucleic acid P.

Section 2. Other Vertebrates

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight; FF = fat-free.

Component					Component				
Cat					Sheep				
1 Water, %	70-72	73-75	70-75		2 Calcium	67	78		80
2 Calcium		5.0-22	4.2		3 Chlorine				9.0
3 Chlorine	94-103	149			4 Copper	10-135	1.3-3.5*	0.4* ⁴	195
4 Copper	2.0 ¹		5.1 ¹	5.0	5 Iron, total	9-45	6.4*	6-35	105
5 Iron, total					6 Inorganic		2.6*		28-83
6 Inorganic	23.2 ¹		4-5	1.1-3.1	7 Magnesium	73*			11.4
7 Magnesium		80-140 ²	110-175 ²	350-385*	8 Phosphorus				245
8 Phosphorus	280	115-275			9 Potassium				195
9 Potassium	290	120			10 Sodium				205
10 Sodium	76				11 Zinc		3.0		
11 Zinc	15 ¹		4.3	20	12 Protein, %				13.2
12 Protein, %	17.1				13 Fat, total, %				6.5
13 Fat, total, %	6.0	4.0 ³	2.0-3.2	6.4	14 Phospholipid, %			2.0-3.4	
14 Phospholipid, %		12.0	2.0-3.0	3.2-4.2	15 Cholesterol, total, %	0.14	0.13*FF	0.3-0.6	
15 Cholesterol, total, %			0.17-0.54	0.4-0.7					

/1/ In the newborn. /2/ Nucleic acid P. /3/ Total lipid. /4/ In the young animal.

Part X: SPLEEN

Section 1: Man, Cattle, Rabbit, Rat.

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight; FF = fat-free.

Component	Man	Cattle	Rabbit	Rat	Component	Man	Cattle	Rabbit	Rat
1 Water, %	76-81		78-79	77-78	13 Phosphorus, RNA ⁴	35	50	65-80	35-85
2 Ash, %	1.5		1.0		14 Silicon	5-20			
3 Bromine	0.23-0.6	0.5			15 Zinc	6-9*		9.3-9.9 ¹	
4 Calcium	9.3				16 Protein, %	17.5			
5 Chlorine	160		150	140-160	17 Collagen, %	0.6-1.5	3.1*FF		3.5*FF
6 Chromium, µg/100 g	1.6				18 Elastin, %	0.13-0.5	4.6*FF		0.6*FF
7 Copper	0.12-1.3	0.65*	2.4 ¹		19 Lipid, total, %	3		0.44	0.8-1.3
8 Iron, total	28			35-40	20 Phospholipid, %	5.5-11.3*			10.8*
9 Inorganic	8.5-17			3.5	21 Cephalin, %	1.6-6.9*			1.2
10 Magnesium	14.2	70-85*			22 Lecithin, %	3-4*			1.1
11 Phosphorus, total	375	90-205 ²		165-260 ²	23 Sphingomyelin, %	0.7-1			0.2
12 DNA ³	75	95	80-95	55-145	24 Cholesterol, %				0.3

/1/ In the newborn. /2/ Nucleic acid P. /3/ Desoxyribonucleic acid P. /4/ Ribonucleic acid P.

Section 2: Other Mammals

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight; FF = fat-free.

Component	Cat	Guinea Pig	Mouse	Swine	Component	Cat	Guinea Pig	Mouse	Swine
1 Water, %					6 Phosphorus, RNA ³	85-150		80	
2 Copper	2 ¹	5.1	4-7 ¹	5.4 ¹	7 Zinc	15 ¹	4.3 ¹	19.9 ¹	3 ¹
3 Iodine, µg/100 g				1.5	8 Collagen, %		0.5-1.5		2.4*FF
4 Iron, inorganic	23.2 ¹	4.1 ¹	16 ¹	8.5 ¹	9 Elastin, %				1.3*FF
5 Phosphorus, DNA ²	75-95		130		10 Cholesterol, %		0.43	0.8	

/1/ In the newborn. /2/ Desoxyribonucleic acid P. /3/ Ribonucleic acid P.

Part XI: KIDNEY

Section 1: Man, Cattle, Rabbit, Rat

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight.

Component	Man	Cattle	Rabbit	Rat	Component	Man	Cattle	Rabbit	Rat
1 Water, %	78-79	75	74-80	75-77	14 Silicon	5-20			
2 Ash, %	0.8	1.1	1.3	1.3-1.5	15 Sodium	165	145-170	150-250	
3 Calcium	19.2	14	5	6-11	16 Uranium, µg/100 g	0.3-1.3			
4 Chlorine	190-210		225	200-320	17 Zinc	5.4			14.4-50*
5 Chromium, µg/100 g	8.5				18 Protein, %	18	15		18
6 Copper	0.2-0.4	1.1	0.014*	0.018*	19 Lipid, total, %	5.3	4.4	1.1	1.1-3
7 Iodine, µg/100 g		2.3	5		20 Phospholipid, %	7.3-9.1*	7.7-9.1*		2.4
8 Iron	41	11-15	9		21 Fatty acids, %	2			
9 Lead	0.14				22 Cephalin, %	2.3-4.3*	2.1*		0.95
10 Magnesium	21	80-85*	13.4	18-25	23 Lecithin, %	4.4-6.6*	5.5*		1.4
11 Manganese, µg/100 g	21-30				24 Sphingomyelin, %	0.6-0.8*	1.6*		0.3
12 Phosphorus	170	260		290 ¹	25 Cholesterol, %	0.3-0.4	0.41		0.3
13 Potassium	170	225-240	340	300-330	26 Citric acid			6	4-8

/1/ Nucleic acid P.

Section 2: Other Mammals

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight; FF = fat-free.

Component	Dog	Guinea Pig	Sheep	Swine	Component	Dog	Guinea Pig	Sheep	Swine
1 Water, %	79	77-84	77-80		6 Phosphorus	50 ¹		1100-1400*	
2 Chlorine	230				7 Potassium	230 FF	220-265		
3 Copper, µg/100 g	14.2*	19.9*	17.8*	2700*	8 Lipid, total, %	2			
4 Iodine, µg/100 g			1.4	1.5	9 Cholesterol		0.5	0.2-0.4	0.4
5 Magnesium			95*		10 Citric acid	1.6	3.9		

/1/ Nucleic acid P.

55. VERTEBRATE TISSUES AND ORGANS: CHEMICAL COMPOSITION (Concluded)

Part XII: EYE

Section 1: Man, Cat, Dog, Horse, Rabbit, Whale, Frog, Perch, Trout

Values are mg/100 g fresh tissue, unless otherwise indicated. * = dry weight; TA = on basis of total ash.

Component	Man		Cat		Dog		Horse		Rabbit		Whale	Frog	Perch	Trout
	Lens	Aqueous Humor	Lens	Aqueous Humor	Aqueous Humor	Aqueous Humor ¹	Vitreous Humor ¹	Lens	Aqueous Humor	Lens	Lens	Lens	Lens	Lens
1 Water, %	68		74			99.7	99.7 ²	69-71						
2 Calcium, %	0.45 TA					6.2	6.8							
3 Chlorine	2.1 TA	410-435 ³		460 ³	430-460	435	415		295-410	0.42*	3.0*	0.09*	0.24	
4 Copper								0.05						
5 Magnesium						2.6	2.2							
6 Nitrogen, total					25-55	27	30							
7 Non-protein					12-40	24	26		11-23					
8 Phosphorus, total	3.4 TA		77	23 ⁴	35 ⁵	22-30 ⁵		42-44						
9 As phosphate	0.54 ⁶				0.8-1.5 ⁶	3.3	3.1		5-8 ³					
10 Potassium	15 TA	13.0-24.5 ⁷		365 ³		19	19.2	450-480 ³	56					
11 Sodium	8 TA	400-415 ³			540-675 ⁸	280	275	50-70 ³	335 ³					
12 Sulfate	1.2*				0.2-0.5 ⁹	6.1	6.2							
13 Zinc								1.3-1.6		3.5*	7.8*	1.6*	0.7	
14 Protein ¹⁰ , total, %	3.2-6.5						21.5 ¹¹		0.05-0.14					
15 Fat, total, %	0.9-2.3													
16 Glucose	25-60	55-110		57 ³	74	98	97	100-125	120-130 ³					
17 Urea				40-55		28	29	19-60	22-70					

/1/ Except for H₂O, values are mg/100 ml fluid. /2/ Lens has 66-69% H₂O. /3/ Mg/100 mg fluid. /4/ Young animal. /5/ Lens. /6/ As P₂O₅. /7/ Vitreous humor. /8/ As NaCl. /9/ As S. /10/ Amino acid composition is roughly the same as that for bovine total lens protein - see Section 2. /11/ Mucoprotein.

Section 2: Cattle.

Values are mg/100 g fresh tissue, unless otherwise indicated. Amino acids are mole % of total protein. * = dry weight.

Component	Choroid	Conjunctiva	Cornea	Aqueous Humor	Vitreous Humor	Iris	Lens	Retina	Sclera	Component	Choroid	Conjunctiva	Iris	Lens
1 Water, %	82-84	81-82	82-84	99		81-82	64	86	70-73	26 Protein, H ₂ O-sol, % ³	9.3-18.1	10.4-16.9	4.0-7.4	
2 Ash, %	1.1-1.4	0.4-1	0.6-0.9	0.85-0.94	0.8-0.9	0.8-1.2	0.68-0.73	0.9-1.0	0.4-0.5	27 H ₂ O-insol, %	8.5	14	11.2	0.9-2.4 ⁵
3 Calcium							6			28 Albumin, % ⁴				
4 Chlorine			280-285	360-515	410		60-69	145	225	29 Collagen, %	4.8	11.2	7.2	
5 Copper	0.3-0.4	0.13-0.21	0.14-0.23	0.01	0.02-0.34	0.18-0.41	0.12-0.24	0.12-0.4	0.14-0.25	30 Elastin, %	1.6	1.1	0.7	
6 Iron	1.3-3.0	0.24-0.3	0.21-0.3	0.02	0.012	0.3-0.4	0.03	0.4	0.4	31 Mucoprotein, %	2.1	1.6	3.3	
7 Magnesium			3	2			8	11	2	32 Pigment protein	3.3		4	
8 Manganese, µg/100 g	17-30	7-11	9.4-12.5	1.0-1.5	2-4.2	21-30	14-22	24-40	8-13	33 Alanine				4.7
9 Phosphorus							90-95			34 Arginine	14.2* ⁶		9.2* ⁶	8.2
10 Potassium			90-95	27	17-30		405	50	71	35 Aspartic acid				7.9
11 Sodium			265		300		45	155	185	36 Cystine	4.2* ⁶		2.2* ⁶	1.8
12 Sulfate							470			37 Glutamic acid				11.0
13 Zinc	0.22	0.16	0.2	0.03	0.03	0.4	0.18-0.33	0.3	0.18	38 Glycine				9.3
14 Lipid, total ¹ , %							0.32			39 Histidine	1.6* ⁶		1.3* ⁶	3.5
15 Phospholipid, %							0.19	0.09		40 Isoleucine				5.7
16 Inositol	29-35 ²	6	6.5-8.0		+	22-35	125-175	13.4-17	10.5-14	41 Leucine				7.4
17 Citric acid	2.4-4.3 ²	1.0	1.1-1.5		0.9-1.2	1.3-1.7	1.8-2.4	1.0-1.6	1.1-1.5	42 Lysine	1.3* ⁶		5.2* ⁶	4.8
18 Formic acid	1.6-2.1		0.8-1.6		0.8-1.7	1.9-3.5	1.0-1.2	0.8-1.4	0.9-1.3	43 Methionine				2.0
19 Lactic acid							55-65			44 Phenylalanine				6.5
20 Malic acid	18.5-29	6.5	8.8-14.9		7.7-8.1	10.4-13.3	9.9-13.5	12.9-13.9	6.9-8.1	45 Proline				2.6
21 Hyaluronic acid				4.0	62					46 Serine				9.2
22 Creatine	37-55		25-35		2.1-5.3	45-70		45-80	7.7-13.7	47 Threonine				3.5
23 Creatinine	2.1-2.5	1.1-1.9	1-1.2		0.85-1.1	1.1-1.3	0.86-1.2	1.3-1.5	0.85-1.1	48 Tryptophan	0.75* ⁶		0.73 ⁶	1.5
24 Spermine	3.1-4.2	2.1-2.9	4.9-8.8		0	35-40	2.9-5.8	25-35	0.1-0.3	49 Tyrosine	4.8* ⁶		4.7*	4.7
25 Carnosine	16.1-17.8	9.9-11.3	4.4-4.7		0.16-0.29	3.2-4.1	4.7-5.7	2.6-3.0	1.7-2.6	50 Valine				5.7

/1/ In the lens the following lipid components are also present (as mg/100 g tissue): fatty acids, 1.0; cephalin, 31; lecithin, 125; sphingomyelin, 38; cholesterol, 65; cerebroside, 4.2; unsaponifiable substances, 55. /2/ Choroid + pigmented epithelium. /3/ In lens, α-crystallin = 32%, and β-crystallin = 53% of total protein. /4/ Albumin + globulin: choroid, 2.4%; iris, 1.0%; sclera, 0.6% of total protein. /5/ % of total protein. /6/ % of mucoprotein.

Part XIII: SKIN

Section 1: Man

Values are mg/100 g fresh, non-fat-free whole skin, unless otherwise indicated. * = dry weight.

Component	Value	Component	Value	Component	Value	Component	Value
1 Water, %	70-75 ¹	14 Nitrogen, combined amino acid	20-51	27 Collagen, %	35-40 ¹	40 Histamine	0.1-0.24
2 Ash, %	1.4-2.6 ^{*1}	15 Free amino acid N	17-31	28 Lipid, total, %	0.3-10	41 Hyaluronic acid	19-30
3 Boron	1.7-17.2 [*]	16 Creatine N	0.4-0.6	29 Fats and fatty acids, %	1.0	42 Urea	330 ²
4 Calcium	8.6-12.8 ¹	17 Creatinine N	1.1-1.6	30 Cholesterol, total	370 ^{*1}	43 Ascorbic acid	0.2-0.7 [*]
5 Chlorine	265-300 ¹	18 Urea N	6-11.5	31 Combined	160	44 Biotin, µg/100 g	2.3-8.5 [*]
6 Copper	3-19 ^{*1}	19 Uric acid N	1.0-1.3	32 Free	85	45 Choline	120
7 Iodine	0.15-0.2 [*]	20 Ammonia N	17-46	33 7-Dehydrocholesterol	430 ²	46 Cobalamin, µg/100 g	1.6-2.4 [*]
8 Iron	0.9-5.9 [*]	21 Phosphorus	30-105 [*]	34 Δ-7-Cholestanol	1500 ²	47 Folic acid, µg/100 g	0.9-15 [*]
9 Lead	25-135 [*]	22 Potassium	51-77 ¹	35 Ergosterol, % total sterols	0.42	48 Inositol	23-79 [*]
10 Magnesium	4.5-5.9 ¹	23 Silicon, %	0.64-2.1 [*]	36 Glucose	55-80	49 Pantothenate	0.13-0.71
11 Nitrogen, total, %	16.1 ^{*1}	24 Sodium	205-260 ¹	37 Glycogen	45-115	50 Pyridoxine	18-66 [*]
12 Non-protein, %	3.0 ^{*1}	25 Sulfur	290-340 [*]	38 Sugar, non-fermentable	12	51 Nicotinic acid	0.9-2.4 [*]
13 Collagen, %	11.3 ^{*1}	26 Zinc	1.2-5.5 ¹	39 Chondroitin H ₂ SO ₄	20-30	52 Riboflavin	1.2-3.4 [*]
						53 Thiamine	20-40 [*]

/1/ Fat-free tissue. /2/ Epidermis.

Section 2: Other Vertebrates

Values are mg/100 g fresh, non-fat-free whole skin, unless otherwise indicated. * = dry weight.

Component	Dog ^{*1}	Guinea Pig ^{*1}	Mouse ²	Rabbit	Rat ¹	Frog	Eel	Component	Dog ^{*1}	Guinea Pig ^{*1}	Mouse ²	Rabbit	Rat ¹	Frog	Eel
1 Water, %	68-74		60	67-69 ¹	205 [*]		66-68	8 Potassium	275-390	215-245	345	100-190 [*]	370-445 [*]	130-145	150
2 Ash, %				0.72				9 Sodium	605-890	350-410	125	115-245 [*]	210-245 [*]	90	145
3 Calcium	31-58	32-100	44	50-85 [*]	64-87	300	670	10 Protein, %	26-32 ³	34.4 ^{3,4}			25-30 ⁴		25-26
4 Chlorine	960-1185	570-1815		250-265 ¹	635-1440 [*]	170	155	11 Collagen N, %	10.5-12 ⁴	2 ^{3,4}			25-30		
5 Iron			6.4				5.3	12 Lipid, total, %	25 ^{3,4}		28.6	1.6	13-17 ⁴		
6 Magnesium	18-27	30-55	19	15-50 [*]	20-28 [*]	4	19.4	13 Fat, total, %	16-48 ^{3,4}			1	1.9-7.6		5-6
7 Phosphorus					345 ^{*3}	340	405	14 Cholesterol				425-630 [*]	305-465 ⁴		

/1/ Fat-free tissue. /2/ Epidermis. /3/ Fresh tissue. /4/ Non-fat-free.

Part XIV: KERATINOUS APPENDAGES OF THE SKIN

Section 1: Hair: Man

Values are mg/100 g fresh hair, unless otherwise indicated. Unspec. = type and color not specified.

Component	Unspec.	Brown	Black	Component	Unspec.	Brown	Black	Component	Unspec.	Brown	Black
1 Water, %	4.1	4.0	4.2	8 Chromium	0.2			15 Phosphorus	♂80	♀65	♀95
2 Ash, %	0.23-0.73 ¹	0.9 ²	0.53	9 Cobalt	♂1.8	♀1.4	♀1.6	16 Sulfur, %	♂3.8	♀3.8	
3 Aluminum	♂3.2	♀2.6	♀2.6	10 Copper	♂10.8	♀6.3	♀6.4	17 Uranium, µg/100 g	♀12.7		
4 Arsenic	♂0.22	0.24	0.22	11 Iron	♂14.1	♀13.3	♀12.6	18 Zinc	♂21.2	♀11.6	18.2
5 Bromine	0.2-0.7			12 Lead	♂4.8	♀2.1	♀28.4	19 Sugars ³	80		
6 Calcium	♂20.8	♀21.2	♀18.8	13 Manganese	♂3.8	♀2.8	♀2.5	20 Pentose	30		
7 Chlorine, %	♂2.0	♀2.0	♀2.0	14 Nickel	♂0.8	♀0.5	♀0.55	21 Protein	91	85	85

/1/ Dry weight, fat-free. /2/ Red hair. /3/ Reducing substances determined as glucose.

Section 2: Hair and Other Appendages: Vertebrates Other Than Man

Values are mg/100 g fresh weight hair or other tissue, unless otherwise indicated.

Component	Cat	Cattle	Chimpanzee	Dog	Guinea Pig ¹	Hedgehog	Horse	Mouse	Rabbit ²	Rat	Sheep	Swine	Man	Cattle	Horse	Chicken
													Nail	Horn	Hoof	Feather
1 Water, %									10-13		9-28	11.4	0.07-0.72			9.1
2 Chromium									0.9-4.1	1.4-3.2 ³			0.12			
3 Copper																
4 Lead		0.6	4.2-4.4 ⁴		0.1-4.7		2.9				1-3				2.2	
5 Sulfur, %		3.6-3.9 ⁴		17.2	0.04-0.64						3.2-3.9		3.3-3.5			
6 Zinc						4.9					16.4		10.8 ⁵	12.9 ⁵		
7 Sugars ⁶	250								230	130 ³	200				90	73
8 Pentose									200	60 ³	50					
9 Protein, %		91-100 ⁷	104 ⁷				98		450	640-830 ⁸						
10 Cholesterol							27.7	95-135								
11 Citric acid																

/1/ Black, brown, white. /2/ Various colors. /3/ White. /4/ Dry weight, ash-free. /5/ Dry weight. /6/ Reducing substances determined as glucose. /7/ Nitrogen x 6.25. /8/ Total sterols.

56. INSECT TISSUES: CHEMICAL COMPOSITION

Constituent	Organism	Stage	Tissue			Constituent	Organism	Stage	Tissue				
			Type ¹	Con- dition	Value ²				Type ¹	Con- dition	Value ²		
1 Allantoin	Silkworm, Chinese oak (<i>Antheraea pernyi</i>)	Larva	FB	Wet	82 mg %	60 Lipids (concluded)	Mealworm, yellow (<i>Tenebrio molitor</i>)	Larva	W	Wet	7.8-15.7%		
2 Aluminum	Bee, honey (<i>Apis mellifera</i>)	Adult	W	Dry	0.01%	61	Moth, codling (<i>Carpocapsa pomonella</i>)	Pupa	W	Dry	44%		
3 Amino acids	Mosquito spp	Adult	W		+	62	Silkworm (<i>Bombyx mori</i>)	Adult	W	Dry	24%		
4	Silkworm (<i>Bombyx mori</i>)	Adult	W		+	63	Ant, red (<i>Formica rufa</i>)	Adult	H	Dry	0.3%		
5	Blowfly, Australian sheep (<i>Phaenicia cuprina</i>)	Larva	FB		21 mg %	64	Beetle, water (<i>Gyrinus natator</i>)	Adult	W	Wet	0.0007%		
6 Ammonia	Blowfly, Australian sheep (<i>P. cuprina</i>)	Larva	RHG		540 mg %	65	Butterfly, Eur. cabbage (<i>Pieris brassicae</i>)	Adult	W	Wet	0.00025%		
7	Silkworm, Chinese oak (<i>Antheraea pernyi</i>)	Larva	FB	Wet	13 mg %	66	Crickets, Eng. green (<i>Tettigonia viridissima</i>)	Adult	W	Wet	0.0004%		
8 Ascorbic acid	Beetle, diving (<i>Dytiscus marginalis</i>)	Adult	G	Wet	0.031%	67	Hornet, bald-faced (<i>Vespa maculata</i>)	Larva	GW	Dry	0.13%		
9 Barium	Many insects from various families	Adult	W		+	68	Locust, desert (<i>Schistocerca gregaria</i>)	Adult	W	Ash	0.16%		
10 Boron	Mealworm, yellow (<i>Tenebrio molitor</i>)	Larva	W		+	69	Locust, desert (<i>S. gregaria</i>)	Adult	W	Ash	0.009%		
11	Bee, honey (<i>Apis mellifera</i>), drone	Pupa	W	Dry	1-1.6%	70	Silkworm (<i>Bombyx mori</i>)	Pupa	W		?		
12 Chitin	Bee, honey (<i>A. mellifera</i>), worker	Pupa	W	Dry	4.8%	71	Nitrogen, amino	Moth, cynthia (<i>Samia cynthia</i>)	Pupa	W	Wet	0.2%	
13	Fly, horse bot- (<i>Gasterophilus intestinalis</i>)	Larva	W	Dry	5-9%	72		Moth, pine hawk- (<i>Sphinx pinastri</i>)	Pupa	W	Wet	0.2%	
14	Silkworm (<i>Bombyx mori</i>)	Larva	W	Wet	0.04-0.08 %	73	Silkworm, Chinese oak (<i>Antheraea pernyi</i>)	Pupa	W	Wet	0.2%		
15	Mealworm, yellow (<i>Tenebrio molitor</i>)	Larva	W	Wet	0.1-0.6%	74	Nitrogen, non-protein	Moth, emperor (<i>Eudia pavonia</i>)	Adult	W	Wet	0.6%	
16 Cholesterol	Moth, privet hawk- (<i>Sphinx ligustri</i>)	Pupa	W	Wet	0.09%	75		Moth, pine hawk- (<i>Sphinx pinastri</i>)	Adult	W	Wet	0.5%	
17	Silkworm, Chinese oak (<i>Antheraea pernyi</i>)	Pupa	W	Wet	0.07%	76	Silkworm, Chinese oak (<i>Antheraea pernyi</i>)	Adult	W	Wet	0.8%		
18	Bee, honey (<i>Apis mellifera</i>)	Adult	W	Dry	0.006%	77	Nitrogen, total	Bee, honey (<i>Apis mellifera</i>), drone	Adult	W	Dry	11.6%	
19	Beetle, confused flour- (<i>Tribolium confusum</i>)	Pupa	W	Wet	26 mg/kg	78		Bee, honey (<i>A. mellifera</i>), worker	Adult	W	Dry	11.5-13.4%	
20	Cockroach, American (<i>Periplaneta amer.</i>)	Adult	W	Wet	31 mg/kg	79		Beetle, Japanese (<i>Popillia japonica</i>)	Pupa	W	Wet	1.9-2.9%	
21	Cockroach, oriental (<i>Blatta orientalis</i>)	Adult	W	Wet	14-24 mg/kg	80		Caterpillar, east. tent- (<i>Malacosoma amer.</i>)	Adult	W	Dry	9.0%	
22	Fly, horse bot- (<i>Gasterophilus intestinalis</i>)	Larva	W	Wet	13 mg/kg	81		Blowfly (<i>Phaenicia sericata</i>)	Egg	W	Dry	12.5%	
23	Grasshopper, differential (<i>Melanoplus diff.</i>)	Egg	W	Wet	28 mg/kg	82	Silkworm (<i>Bombyx mori</i>)	Larva	W	Wet	0.9-3.3%		
24	Silkworm (<i>Bombyx mori</i>)	Larva	W		0.002%	83	Phospholipid	Mealworm, yellow (<i>Tenebrio molitor</i>)	Larva	W	Wet	0.6-2.2%	
25	Silkworm, cecropia (<i>Samia cecropia</i>)	Pupa	W	Wet	10 mg/kg	84	Phosphorus, inorganic	Moth, emperor (<i>Eudia pavonia</i>)	Adult	W	Wet	0.03-0.07%	
26	Beetle, potato (<i>Leptinotarsa decemlineata</i>)	Adult	W	Wet	1.5-15%	85		Moth, hawk (<i>Deilephila euphorbiae</i>)	Adult	W	Wet	0.11-0.18%	
27	Locust, migratory (<i>Melanoplus mexicanus mex.</i>)	Adult	W	Dry	2.4%	86		Moth, privet hawk- (<i>Sphinx ligustri</i>)	Adult	W	Wet	0.03-0.06%	
28	Mealworm, yellow (<i>Tenebrio molitor</i>)	Larva	W	Wet	6.6-14.3%	87	Silkworm, Chinese oak (<i>Antheraea pernyi</i>)	Adult	W	Wet	0.02-0.04%		
29	Scale, white wax (<i>Ceroplastes destructor</i>)	Adult	Wax		22%	88	Phosphorus, labile	Moth, hawk (<i>Deilephila euphorbiae</i>) ♂	Adult	W		9.2 mg %	
30	Silkworm (<i>Bombyx mori</i>)	Larva	W	Wet	0.5-4.8%	89		Moth, hawk (<i>D. euphorbiae</i>) ♀	Adult	W		110 mg %	
31	Beetle, diving (<i>Dytiscus marginalis</i>)	Adult	MT	Wet	100 mg %	90	Phosphorus, total	Moth, emperor (<i>Eudia pavonia</i>)	Pupa	W	Wet	2 g/kg	
32	Cricket, house (<i>Acheta domesticus</i>)	Adult	MT	Wet	8 mg %	91		Moth, hawk (<i>Deilephila euphorbiae</i>)	Adult	W	Wet	0.18-0.41%	
33	Fly, horse bot- (<i>Gasterophilus intestinalis</i>)	Larva	W	Wet	1.2 mg %	92		Moth, privet hawk- (<i>Sphinx ligustri</i>)	Pupa	W	Wet	2.7 g/kg	
34	Locust, desert (<i>Schistocerca gregaria</i>)	Adult	MT	Wet	200 mg %	93	Silkworm, Chinese oak (<i>Antheraea pernyi</i>)	Pupa	W	Wet	2.3 g/kg		
35	Flavins	Mealworm, yellow (<i>Tenebrio molitor</i>)	Adult	MT	Wet	16 mg %	94	Potassium	Mosquito (<i>Aedes aegypti</i>)	Adult	MG & MT	Dry	15.6 mg/g
36		Moth, goat (<i>Cossus cossus</i>)	Larva	W	Wet	2.3 mg %	95	Reducing substances, as glucose	Beetle, Japanese (<i>Popillia japonica</i>)	Adult		Wet	1.0%
37		Moth, privet hawk- (<i>Sphinx ligustri</i>)	Pupa	MT	Wet	150 mg %	96	Fly, house (<i>Musca domestica</i>)	Adult		Wet	0.8-1.2%	
38		Roach, oriental (<i>Blatta orientalis</i>)	Adult	MT	Wet	10 mg %	97	Moth, wax (<i>Galleria mellonella</i>)	Larva	W	Wet	0.2-0.3%	
39		Silkworm, Chinese oak (<i>Antheraea pernyi</i>)	Adult	W	Wet	0.8 mg %	98	Silicon ³	Locust, migratory (<i>Melanoplus mexicanus mex.</i>)	Adult	W	Dry ⁴	11.9% ⁴
40	Armyworm, southern (<i>Prodenia eridania</i>)	Adult	W	Dry	0.8-2.9 %	99	Sodium	Mosquito (<i>Aedes aegypti</i>)	Adult	MG & MT	Dry	6.9 mg/g	
41	Bee, honey (<i>Apis mellifera</i>)	Larva	W	Dry	0-32.5%	100	Strontium	Many insects from various families	Adult			+	
42	Caterpillar, tent (<i>Malacosoma armigera</i>)	Larva	W	Dry	0.4-3%	101	Sulfur	Locust, migratory (<i>Melanoplus mexicanus mex.</i>)	Adult	Fat	Dry	0.02%	
43	Fly, horse bot- (<i>Gasterophilus intestinalis</i>)	Larva	W	Dry	14-31%	102	Titanium ⁵	Locust, desert (<i>Schistocerca gregaria</i>)	Adult	W	Dry ⁴	0.16% ⁴	
44	Moth, spurge hawk- (<i>Deilephila euphorbiae</i>)	Pupa	W	Dry	0.78%	103		Silkworm (<i>Bombyx mori</i>)	Egg	W	Wet	24-29 mg %	
45	Moth, wax (<i>Galleria mellonella</i>)	Pupa	W	0		104		Silkworm, Chinese oak (<i>Antheraea pernyi</i>)	Larva	FB	Wet	29 mg %	
46	Silkworm (<i>Bombyx mori</i>)	Larva	W	Dry	0.5-1.2%	105	Urea	Blowfly (<i>Phaenicia sericata</i>)	Egg	W	Wet	18 mg %	
47	Bee, honey (<i>Apis mellifera</i>)	Adult	W	Dry	0.00009%	106		Silkworm (<i>Bombyx mori</i>)	Egg	W	Dry	1.7-3.6 mg/g	
48	Beetle, forest may- (<i>Melolontha melolontha</i>)	Adult	W	Wet	0.1 %	107		Silkworm, Chinese oak (<i>Antheraea pernyi</i>)	Larva	FB	Dry	6.75 mg/g	
49	Beetle, water (<i>Hydrous piceus</i>)	Adult	W	Wet	0.08%	108	Water	Beetle, confused flour- (<i>Tribolium conf.</i>)	Pupa	W		59.8%	
50	Fly, house (<i>Musca domestica</i>)	Adult	W	Wet	0.03%	109		Blowfly (<i>Phaenicia sericata</i>)	Egg	W		79%	
51	Bee, honey (<i>Apis mellifera</i>)	Adult	W	Dry	0.01%	110		Cockroach, American (<i>Periplaneta amer.</i>)	Adult	W		61%	
52	Grasshopper, differential (<i>Melanoplus diff.</i>)	Egg	W	Wet	0.12%	111		Cockroach, oriental (<i>Blatta orientalis</i>)	Adult	W		70.6%	
53	Lactic acid	Fly (<i>Gasterophilus spp</i>)	Larva	W	Wet	0.03-0.11%		112	Fly, blue bottle- (<i>Cynomyopsis cadaverina</i>)	Larva	W		73.3%
54	Bee, honey (<i>Apis mellifera</i>)	Larva	W	Dry	18.0%	113	Fly, horse bot- (<i>Gasterophilus intestinalis</i>)	Larva	W		64.7%		
55	Cockroach, American (<i>Periplaneta amer.</i>)	Adult	W	Dry	25.5-28.6%	114	Silkworm (<i>Bombyx mori</i>)	Larva	O		75-94%		
56	Cockroach, German (<i>Blattella germanica</i>)	Adult	W	Dry	15.6-17%	115	Silkworm, cecropia (<i>Samia cecropia</i>)	Pupa	W		71.8%		
57	Fly, horse bot- (<i>Gasterophilus intestinalis</i>)	Larva	W	Dry	12.7-26%	116	Weevil, bean (<i>Acanthoscelides obtectus</i>)	Adult	W		48.2%		
58	Fly, tsetse (<i>Glossina morsitans</i>)	Adult	W	Dry	16.2-35.3%	117	Zinc	Beetle, ground (<i>Carabus auratus</i>)	Adult	W	Wet	0.18 g/kg	
59	Grasshopper, differential (<i>Melanoplus diff.</i>)	Egg	W	Dry	17-22%	118		Fly, house (<i>Musca domestica</i>)	Adult	W		Trace	

/1/ FB = fat body; G = gut; H = head; GW = gut wall; MG = midgut; MT = malpighian tubes; O = ovary; RHG = rear hindgut; W = whole. /2/ mg % = mg per 100 g tissue. /3/ As SiO₃. /4/ Per cent of total ash. /5/ As TiO₂.

57. WHOLE ORGANISMS AND HUMAN TISSUES: "B" VITAMIN CONTENT

Values for whole organisms are mg per 100g dry organism, and for human tissues are mg per 100g wet tissue. Ranges represent estimate "d" of the 95% range (cf. Introduction). Too much reliance should not be placed on the exact numerical values since incomplete extractions and other limitations are involved in the methods used.

Organism or Tissue	Biotin	Folic Acid Group ¹	Inositol	Niacin ²	Panto- thenic Acid	Pyridoxine ³ Group	Ribo- flavin	Thiamine
THALLOPHYTA								
Bacteria								
1 Aerobacter aerogenes	0.24-0.39	0.10-0.28	140-160	20-24	14-34	0.7-1.8	4.3	1.1-1.5
2 Azotobacter chroococcum				59.0				3.3-9.6
3 A. vinelandii	0.26-0.42				15.2-18.4		30.5-35.0	
4 Clostridium acidurici							1.4	
5 C. butyricum	0.17	0.05	86	25	9.2	0.62	5.5	0.93
6 Lactobacillus delbrueckii							11.5	
7 Mycobacterium smegmatis							860	
8 M. tuberculosis							15-20	
9 Phytomonas tumefaciens					4.1			1.2
10 Propionibact. pentosaceum								0.04-0.62
11 Proteus vulgaris	0.34	0.42	100	25	10	0.68		2.1
12 Pseudomonas fluorescens	0.71	0.18	170	21.0	9.0	0.57	6.8	2.6
13 Serratia marcescens	0.41	0.32	160	23.5	12.4	0.11	3.5	2.7
Fungi								
14 Aspergillus oryzae								1.8
15 Fusarium graminearum								0.5
16 F. lini								2.0
17 Neurospora sitophila						0.91-1.37		
18 Penicillium chrysogenum	0.06-0.15	1.34-1.46		15.0-21.2	10.7-21.2	2.3	3.98-4.75	0.26
19 P. notatum		0.36-0.45		18.0				0.69
20 Mushrooms	0.14		135	54	13.8		2.6	0.88
Yeasts								
21 Brewer's	0.007		28	12.6	4.2		1.52	0.8
22 Candida arborea	0.03-0.32	1.5-2.0		16.60			4.6-6.9	3.1-3.3
23 Hansenula suaveolens	0.17	0.17		60	18		5.4	0.8
24 Mycotrolula lipolytica	0.18	0.31		60			5.9	0.5
25 Oospora lactis	0.1-0.2	0.6-1.5		19-25			4-5.5	2-2.9
26 Saccharomyces cerevisiae	0.05-0.18	1.9-3.6		19-295	11.8-19.8	1.6-6.5	3.6-7.5	2.9-9
27 Torulopsis utilis	0.11-0.19	0.4-3.1	340-360	21-53	8.6-18	3.5	2.6-6.2	0.6-5.3
EMBRYOPHYTA								
28 Bean, lima	0.012		180	1.2	0.9		0.14	0.57
29 Peas, black-eyed	0.022		250	1.4	1.1		0.15	0.85
30 Wheat seed	0.006		190	4.5	1.3		0.18	0.55
31 PROTOZOA	0.075		330	9.0	10.5		1.7	3.8
MOLLUSCA								
32 Oyster	0.053		270	7.3	3.0		1.3	1.1
ANNELIDA								
33 Earthworm	0.025		52	4.8	1.0		2.5	0.78
INSECTA								
34 Ant, red	0.037		220	4.7	2.9		1.4	0.73
35 Cockroach	0.048		134	12.0	6.5		2.6	1.62
36 Fly, fruit, larva	0.205		93	21.0	11.6		4.7	2.4
37 Termite	0.066		215	17.5	8.8		2.65	1.28
VERTEBRATA								
38 Chick ⁴	0.175		118	40.5	37.0		1.34	0.83
39 Fish	0.031		88	7.8	2.4		0.52	0.95
40 Frog	0.057		123	5.3	1.7		1.14	0.64
41 Rat	0.033		56	18.0	3.8		1.05	0.50
42 Snake	0.025		107	14.2	2.5		4.5	0.51
43 Toad, horned	0.07		210	17.0	3.6		2.1	1.1
HUMAN TISSUES								
44 Adrenal	0.035		69	2.4	0.8		0.82	0.16
45 Brain	0.058		151	2.0	1.5		0.25	0.16
46 Colon	0.009		78	1.3	0.5		0.21	0.10
47 Heart	0.017		50	4.1	1.6		0.83	0.36
48 Ileum	0.006		75	1.9	0.53		0.42	0.055
49 Kidney	0.067		124	3.7	1.9		2.0	0.28
50 Liver	0.074		66	5.8	4.3		1.6	0.22
51 Lung	0.019		40	1.8	0.5		0.19	0.15
52 Mammary gland	0.004		27	1.0	0.39		0.24	0.043
53 Ovary	0.0025		58	1.8	0.39		0.43	0.061
54 Seminal ducts	0.0015		<10	0.92	0.20		0.10	0.069
55 Skeletal muscle	0.0035		45	4.7	1.2		0.20	0.12
56 Skin	0.0022		20	0.86	0.31		0.12	0.052
57 Smooth muscle	0.006		58	3.1	0.62		0.23	0.12
58 Spleen	0.006		103	2.3	0.54		0.36	0.11
59 Stomach	0.019		76	1.9	0.61		0.52	0.056
60 Testes	0.009		160	1.6	0.5		0.20	0.08

/1/ Pteroylglutamic acid (folacin), vitamin M, B₉, factor U, L. casei factor, Norite eluate factor. /2/ Nicotinic acid and nicotinamide. /3/ Includes pyridoxine, pyridoxal, pyridoxamine. /4/ Embryo.

58. VERTEBRATE TISSUES AND ORGANS: RELATIVE ENZYME CONTENT

Methods by which values have been derived, and units of measurement, are listed numerically at the end of the table and are assigned, by numbers in brackets, to the appropriate enzymes. Values in parentheses are ranges and, unless accompanied by superscript, represent estimate "d" of the 95% range (cf. Introduction).

Animal Tissue or Organ Concentration			Animal Tissue or Organ Concentration			Animal Tissue or Organ Concentration					
Aconitase [1]			Choline Acetylase [10]			Esterase, Choline [18] (concluded)					
1	Rat	Brain	10.0	71	G. pig	Cardiac muscle	19.5	141	Rat	Salivary gland	1.6
2	Rat	Intest. mucosa	7.8	72	G. pig	Kidney	0.0	142	Rat	Skin	3.0
3	Rat	Kidney	80	73	G. pig	Liver	0.0	Esterase, True (Acetylcholine) [19]			
4	Rat	Liver	61.5	74	G. pig	Skel. muscle	16.2(10.5-22.2)	143	Cat	Cer. symp. ga.	28.4
5	Rat	Lung	14.5	75	Pigeon	Breast muscle	32.8(30.4-34.4)	144	Cat	Sciatic nerve	0.7
6	Rat	Salivary gland	11.9	76	Rabbit	Cardiac muscle	63(58.6-67.3)	145	Cat	Symp. fiber	3.7
7	Rat	Testes	7.6	77	Rabbit	Sciatic nerve	60	146	Dog	Brain cortex	(2-3)
Adenosinetriphosphatase [2]			Dehydrogenase, Alcohol [6]			147	Dog	Cer. symp. ga.	14.0		
8	Rat	Brain	7.0	78	Horse	Liver	1.0	148	Dog	Lenticular n.	70
9	Rat	Cardiac muscle	27.3	Dehydrogenase, Glutamic Acid [11]			149	Dog	Symp. fiber	5.0	
10	Rat	Kidney	20.3	79	Rat	Brain	10.3(6.2-15.5) ^c	150	Eel	Elect. org. ant.	(400-500)
11	Rat	Liver	12.9	80	Rat	Cardiac muscle	4.9(0-8.0) ^c	151	elect.	Elect. org. post.	100
12	Rat	Lung	21.8	81	Rat	Kidney	24.7(19.3-29.1) ^c	152	G. pig	Brain cortex	1.3
13	Rat	Pancreas	11.5	82	Rat	Liver	49.3(37.2-62.8) ^c	153	G. pig	Cer. symp. ga.	12.8
14	Rat	Submaxillary gl.	16.4	83	Rat	Spleen	5.2(3.5-6.8) ^c	154	Ox	Brain cortex	1.5
15	Rat	Skel. muscle	23.3	Dehydrogenase, Isocitric [12]			155	Ox	Caudate nerve	5.9	
16	Rat	Spleen	13.0	84	Mouse	Liver	2.64	Fumarase [6]			
Aldolase [3]			Dehydrogenase, Lactic Acid [13]			156	Swine	Cardiac muscle	0.02		
17	Rabbit	Blood	0.018	85	Mouse	Brain	228	β -n-Galactosidase [20]			
18	Rabbit	Cardiac muscle	0.62	86	Mouse	Cardiac muscle	292	157	G. pig	Liver	12.0
19	Rabbit	Skel. muscle	7.5(3.44-8.5)	87	Mouse	Gastric mucosa	201	158	G. pig	Spleen	6.0
20	Rat	Brain	0.34(0.14-0.72)	88	Mouse	Intest. mucosa	732	159	Mouse	Liver	6.5
21	Rat	Cardiac muscle	0.62	89	Mouse	Kidney	367	160	Mouse	Spleen	13.0
22	Rat	Kidney	0.35	90	Mouse	Liver	428	161	Rat	Adrenal	20-33
23	Rat	Liver	0.33(0.18-0.56)	91	Mouse	Lymph node	209	162	Rat	Brain	1.5
24	Rat	Skel. muscle	7.5(3.44-8.5)	92	Mouse	Pancreas	155	163	Rat	Cardiac muscle	2.0
25	Rat	Spleen	0.22(0.10-0.33)	93	Mouse	Skel. muscle	972	164	Rat	Kidney	36.0
Arginase [4]			94	Mouse	Spleen	144	165	Rat	Liver	18.0	
26	Mouse	Bone marrow	4.0	95	Mouse	Testes	206	166	Rat	Pancreas	6.0
27	Mouse	Brain	3.0	Dehydrogenase, Malic Acid [14]			167	Rat	Salivary gland	5-11	
28	Mouse	Cardiac muscle	7.0	96	Mouse	Brain	42.2	168	Rat	Spleen	14-20
29	Mouse	Gastric mucosa	4.0	97	Mouse	Liver	100(97-103)	169	Rat	Thyroid	31-36
30	Mouse	Intest. mucosa	80	98	Pigeon	Skel. muscle	107.0	170	Rat	Uterus	13-15
31	Mouse	Kidney	42	99	Rat	Brain	27.5(27.2-27.8)	β -Glucuronidase [21]			
32	Mouse	Liver	246	100	Rat	Kidney	81(70-90)	171	Rat	Adrenal	4.6
33	Mouse	Lung	50	101	Rat	Liver	103(73-125)	172	Rat	Kidney	5.3
34	Mouse	Pancreas	8.0	Dehydrogenase, Succinic Acid [15]			173	Rat	Liver	16.0	
35	Mouse	Skel. muscle	4.0	102	Rat	Brain	19.2(13.3-25.1)	174	Rat	Lung	5.2
36	Mouse	Skin	27	103	Rat	Cardiac muscle	97.9(78.1-117.7)	175	Rat	Prostate	3.0
37	Mouse	Spleen	6.0	104	Rat	Kidney	138(99.7-176)	176	Rat	Skel. muscle	0.1
38	Rat	Brain	3.0	105	Rat	Liver	66.4(58.8-76.0)	177	Rat	Spleen	25.3
39	Rat	Kidney	60	106	Rat	Lung	16.2(12.7-19.7)	178	Rat	Testes	0.1
40	Rat	Liver	213	107	Rat	Skel. muscle	16.1(11.7-20.5)	179	Rat	Uterus	6.8
41	Rat	Pancreas	4.0	Desoxyribonuclease [16]			Hexokinase [22]				
42	Rat	Skel. muscle	8.0	108	Mouse	Bone marrow	7.0	180	Rat	Brain	27.1(20.3-31.2) ^c
43	Rat	Spleen	10.0	109	Mouse	Brain	4.0	181	Rat	Cardiac muscle	14.5(9.2-17.9) ^c
Asparaginase I [5]			110	Mouse	Cardiac muscle	9.0	182	Rat	Kidney	7.9(6.3-11.0) ^c	
44	Rat	Brain	1.0	111	Mouse	Gastric mucosa	6.0	183	Rat	Liver	1.4(0.2-2.6) ^c
45	Rat	Kidney	4.0	112	Mouse	Intest. mucosa	15.0	184	Rat	Lung	4.3(2.9-4.6) ^c
46	Rat	Liver	3.0	113	Mouse	Kidney	10.0	185	Rat	Pancreas	5.6(4.0-7.4) ^c
47	Rat	Spleen	1.0	114	Mouse	Liver	14.0	186	Rat	Small intestine	11.7(9.3-13.3) ^c
Asparaginase II [5]			115	Mouse	Lung	8.0	187	Rat	Spleen	8.3(7.3-9.3) ^c	
48	Rat	Brain	0.0	116	Mouse	Lymph nodes	25.0	188	Rat	Testes	13.7(11.4-18.8) ^c
49	Rat	Kidney	4.0	117	Mouse	Pancreas	5.0	189	Rat	Uterus	8.5(6.0-10.9) ^c
50	Rat	Liver	21.0	118	Mouse	Skel. muscle	12.0	Histaminase [23]			
51	Rat	Spleen	22.0	119	Mouse	Spleen	16.0	190	G. pig	Cardiac muscle	1.30
Carbonic Anhydrase [6]			120	Mouse	Thymus	3.0	191	G. pig	Intest. mucosa	1.54	
52	Cattle	Erythrocytes	0.9	β -n-Glucosidase [17]			192	G. pig	Kidney cortex	0.73	
Carboxylase, Oxalosuccinic [7]			121	Rat	Adrenal	1.5-3.0	193	G. pig	Liver	1.88	
53	Monkey	Brain	45	122	Rat	Brain	2-4	194	G. pig	Lung	0.60
54	Ox	Brain	94	123	Rat	Cardiac muscle	0.8-1.6	195	G. pig	Spleen	0.44
55	Swine	Cardiac muscle	840	124	Rat	Intest. large	5.0	196	Mouse	Brain	0.18
56	Swine	Kidney	230	125	Rat	Intest. small	4-6	197	Mouse	Cardiac muscle	0.73
57	Swine	Liver	80	126	Rat	Kidney	4.8	198	Mouse	Kidney cortex	1.30
58	Pigeon	Breast muscle	740	127	Rat	Liver	1-3	199	Mouse	Liver	0.82
59	Pigeon	Liver	60	128	Rat	Pancreas	(0.2-1.5)	200	Mouse	Lung	1.17
Carboxypeptidase [8]			129	Rat	Salivary gland	(0.6-2.5)	201	Mouse	Spleen	0.74	
60	Dog	Duodenal fluid	(0.2-0.3)	130	Rat	Spleen	3-5	202	Swine	Kidney cortex	5.00
61	Dog	Pancreas	(1.9-3.0)	131	Rat	Stomach	4.0	203	Swine	Liver	2.30
62	G. pig	Duodenal fluid	(0.2-0.5)	132	Rat	Testes	1-4	204	Rabbit	Cardiac muscle	21.20
63	G. pig	Pancreas	(2.0-4.5)	133	Rat	Thyroid	8-10	205	Rabbit	Kidney cortex	4.80
64	Man	Duodenal fluid	(0.2-0.5)	134	Rat	Uterus	1-3	206	Rabbit	Liver	6.53
65	Man	Pancreas	(2.0-5.0)	Esterase, Choline [18]			207	Rabbit	Lung	21.20	
66	Rat	Duodenal fluid	(0.2-0.6)	135	Rat	Adrenal	2.5	208	Rabbit	Spleen	1.34
67	Rat	Pancreas	(2.5-6.0)	136	Rat	Brain	5.5	209	Rat	Brain	0.72
Catalase [9]			137	Rat	Cardiac muscle	10.8	210	Rat	Cardiac muscle	2.52	
68	Horse	Erythrocytes	0.40	138	Rat	Gastric mucosa	1.5	211	Rat	Kidney cortex	0.93
69	Horse	Liver	1.70	139	Rat	Intest. mucosa	6.5	212	Rat	Liver	0.30
70	Man	Erythrocytes	0.50	140	Rat	Liver	0.9	213	Rat	Lung	8.25

/1/ The pancreas values are for procarboxypeptidase.

58. VERTEBRATE TISSUES AND ORGANS: RELATIVE ENZYME CONTENT (Concluded)

Methods by which values have been derived, and units of measurement, are listed numerically at the end of the table and are assigned, by numbers in brackets, to the appropriate enzymes. Values in parentheses are ranges and, unless accompanied by superscript, represent estimate "d" of the 95% range (cf. Introduction).

Animal	Tissue or Organ	Concentration	Animal	Tissue or Organ	Concentration	Animal	Tissue or Organ	Concentration
Hyaluronidase [24]			Oxidase, Monamine [27] (concluded)			Phosphoprotein Phosphatase [31]		
214	G. pig Adrenal	1.3	259	Swine Cardiac muscle	33	305	Rat Adrenals	1.95(1.12-3.08) ^c
215	G. pig Brain	0.06(0.04-0.10) ^c	260	Swine Intestine	94	306	Rat Bone marrow	0.90(0-1.62) ^c
216	G. pig Kidney	0.32(0.2-0.55) ^c	261	Swine Kidney	435	307	Rat Cardiac muscle	1.28(0.71-1.70) ^c
217	G. pig Liver	0.11(0.06-0.15) ^c	262	Swine Liver	257	308	Rat Gastric mucosa	1.74(1.28-2.28) ^c
218	G. pig Skel. muscle	0.12(0.08-0.15) ^c	263	Swine Pancreas	75	309	Rat Kidney	2.43(1.33-4.21) ^c
219	G. pig Spleen	0.13(0.08-0.21) ^c	264	Swine Spleen	14.0	310	Rat Liver	2.69(1.87-3.74) ^c
220	G. pig Testes	125(100-150) ^c	265	Swine Thyroid	6.0	311	Rat Mammary gland	0.98(0.84-1.15) ^c
221	Mouse Brain	0.08(0.07-0.09) ^c	Phosphoglucosidase [28]			312	Rat Pancreas	0.76(0.72-0.82) ^c
222	Mouse Kidney	0.12(0.09-0.16) ^c	266	G. pig Liver	7.0(5.9-9.6)	313	Rat Salivary gland	1.35(0-3.86) ^c
223	Mouse Liver	0.14(0.08-0.20) ^c	267	G. pig Skel. muscle	32.1(26.4-41.9)	314	Rat Spleen	3.35(0.93-5.48) ^c
224	Mouse Spleen	0.13(0.08-0.17) ^c	268	Rat Liver	2.0(6.5-18.4)	315	Rat Testes	2.03(1.90-2.16) ^c
225	Rabbit Brain	0.03	269	Rat Skel. muscle	34.0(30.7-58.0)	316	Rat Thymus	2.48(2.29-2.58) ^c
226	Rabbit Kidney	0.05	Phosphomonoesterase I (Alk. Phosphatase) [29]			Ribonuclease [32]		
227	Rabbit Liver	0.07	270	Mouse Bone marrow	23.0	317	Rabbit Blood cells	66
228	Rabbit Lung	0.26	271	Mouse Brain	12.0	318	Rabbit Blood, whole	78
229	Rabbit Spleen	0.25	272	Mouse Intest. mucosa	2789	319	Rabbit Bone marrow	1.5
230	Rabbit Stomach	0.07	273	Mouse Kidney	1072	320	Rabbit Pancreas	2.4
231	Rabbit Testes	200	274	Mouse Liver	4.0	321	Rabbit Plasma	16.0
Oxidase, D - Amino Acid [25]			275	Mouse Lung	36	322	Rabbit Spleen	4.7
232	Cat Kidney	645	276	Mouse Pancreas	1.0	323	Rat Blood cells	60
233	Cat Liver	122	277	Mouse Skel. muscle	2.0	324	Rat Blood, whole	126
234	Dog Kidney	(680-1100)	278	Mouse Spleen	17.0	325	Rat Bone marrow	5.4
235	Dog Liver	(306-580)	279	Mouse Submaxillary gl.	23.0	326	Rat Cardiac muscle	0.33
236	G. pig Kidney	32	280	Rat Brain	4.0	327	Rat Kidney	1.63
237	G. pig Liver	27	281	Rat Kidney	1500	328	Rat Liver	0.37
238	Horse Kidney	23.0	282	Rat Liver	4.0	329	Rat Pancreas	16.7
239	Horse Liver	22.0	283	Rat Pancreas	3.0	330	Rat Plasma	42
240	Rat Kidney	(108-132)	284	Rat Plasma	9.0	331	Rat Spleen	2.06
241	Rat Liver	(15-31)	285	Rat Skel. muscle	2.0	Succinoxidase [33]		
Oxidase, L - Amino Acid [6]			286	Rat Spleen	21.0	332	Rat Brain	49(41-64) ^c
242	Rat Kidney	0.20	Phosphomonoesterase II (Acid Phosphatase) [30]			333	Rat Cardiac muscle	219(197-250) ^c
Oxidase, Cytochrome-c [26]			287	Mouse Bone marrow	22.0	334	Rat Kidney	195(174-226) ^c
243	Rat Brain	53	288	Mouse Brain	15.0	335	Rat Liver	88(79-101) ^c
244	Rat Cardiac muscle	218.	289	Mouse Gastric mucosa	27	336	Rat Lung	17.9(15.0-21.6) ^c
245	Rat Kidney	157.9	290	Mouse Intest. mucosa	34	337	Rat Skel. muscle	35.5(29.2-48.7) ^c
246	Rat Liver	62	291	Mouse Kidney	15.0	338	Rat Spleen	23.3(19.4-35.3) ^c
247	Rat Lung	22.9	292	Mouse Liver	12.0	TPN-Cytochrome-c-Reductase [34]		
Oxidase, Monamine [27]			293	Mouse Pancreas	10.0	339	Mouse Liver	0.77
248	Man Cardiac muscle	552	294	Mouse Skel. muscle	19.0	Transaminase [35]		
249	Man Kidney cortex	567	295	Mouse Skin	30	340	Rat Brain	260
250	Man Kidney medulla	252	296	Mouse Spleen	73	341	Rat Cardiac muscle	425
251	Man Liver	1027	297	Mouse Submaxillary gl.	22.0	342	Rat Kidney	245
252	Man Skel. muscle	155	298	Rat Brain	16.0	343	Rat Liver	245
253	Man Uterus	111	299	Rat Kidney	95	344	Rat Lung	51
254	Ox Cardiac muscle	52	300	Rat Liver	25.0	345	Rat Skel. muscle	316
255	Ox Intestine	278	301	Rat Pancreas	18.0	346	Rat Spleen	16.0
256	Ox Kidney	655	302	Rat Plasma	0.4	347	Rat Testes	150
257	Ox Liver	796	303	Rat Skel. muscle	16.0	Tyrosinase [36]		
258	Ox Spleen	97	304	Rat Skin	8.0	348	Mouse Melanoma	1865

[1] Q citrate formed from cis-aconitate at pH 7.4 by rat tissue extract. [2] mg of inorganic phosphate split off ATP per mg fresh rat tissue per 15 min (Ca added). [3] mg phosphorus released per min per g of wet tissue (fructose-1,6-diphosphate substrate). [4] Ratio of % hydrolysis of arginine after 2 hr incubation at 38° to the cube root of total N per ml of tissue extract. [5] μ M asparagine deaminated per ml of tissue extract at pH 8.4. [6] Grams of pure enzyme per kg whole tissue. [7] mm^3 CO_2 evolved from substrate per hr per mg of protein calculated from the first 5 min of reaction (oxalosuccinic acid substrate). [8] mg of carboxypeptidase per g or ml of fresh tissue homogenate or fluid. [9] Grams catalase per kg wet tissue (H_2O_2 substrate). [10] μ g acetylcholine formed per hr per g wet tissue. [11] QO_2 per 10 min per 10 mg of tissue at 38°. [12] μ M TPN reduced per min per 100 mg of fresh tissue. [13] Moles $\times 10^{-8}$ pyruvate reduced per min per mg total homogenate nitrogen at 26°. [14] μ l O_2 consumed per 10 min per 20 mg fresh tissue. [15] $\Delta \log$ (ferricytochrome-c) per min per mg tissue protein. [16] In terms of the decrease in viscosity after $\frac{1}{2}$ hr incubation at 30° of a mixture containing 3 ml of 1% sodium thymonucleate and 3 ml of tissue extract (1.23 mg N per ml). [17] μ g of 6-bromo-2-naphthol produced per hr at 37° with 0.6 ml of tissue homogenate supernatant. Determined by colorimetric method using 6-bromo-2-naphthyl- β -D-glucopyranoside as substrate. [18] ml CO_2 liberated during hydrolysis of acetylcholine per g fresh rat tissue per hr. [19] mg acetylcholine hydrolyzed by 100 mg tissue per hr at normal temperature and pressure. [20] μ g of 6-bromo-2-naphthol produced per hr per 0.6 ml of tissue homogenate supernatant at 37°. Determined by colorimetric method using 6-bromo-2-naphthyl- β -D-galactopyranoside as substrate. [21] μ g phenolphthalein liberated from phenolphthalein glucuronide per mg fresh rat tissue per hr. Determined by colorimetric method. [22] μ l of glucose utilized per mg tissue (dry weight) per hr. [23] Expressed as units per g wet tissue; one unit of histaminase activity is defined as the quantity capable of catalyzing the release of NH_3 at the rate of 1 μ M per 24 hr at 10° C. [24] Schering units per g tissue. Activity determined by the "long-time viscosity test" using umbilical cord hyaluronidase as substrate. [25] μ l O_2 consumed per hr per 100 mg dry acetone powdered tissue at 37.5° C. [26] $\Delta \log$ (ferricytochrome-c) per min per mg protein. [27] μ l O_2 consumed per hr per g of wet tissue (tyramine substrate). [28] Decrease in acid labile phosphorus in mg phosphorus per hr per g of tissue (Mg activator, glucose-1-phosphate substrate). [29] Average ratio of % hydrolysis of phenyl phosphate after 1 hr incubation at 38° to the total N per ml of tissue extract at pH 9.5. [30] Average ratio of % hydrolysis of phenyl phosphate after 1 hr incubation at 38° to the total N per ml of tissue extract at pH 4.6. [31] Enzyme units per mg fresh tissue. An enzyme unit corresponds to the number of μ M of phosphorus liberated from casein phosphate per min under experimental conditions. [32] mm^3 CO_2 per min per mg or ml wet tissue (yeast nucleic acid substrate). [33] $\text{QO}_2 = \mu$ l of O_2 taken up in the oxidation of succinate per hr per mg of dry tissue (cytochrome-c and succinate substrate). [34] μ M cytochrome-c reduced per min per 100 mg fresh tissue. [35] μ l substrate transaminated per hr per mg dry tissue (glutamic acid and oxalacetic acid substrate). [36] μ l O_2 consumed per min per g tissue (1 mg tyrosine substrate).

59. CELL SAP: PHYSICAL PROPERTIES
Data applicable to sap of leaves except as otherwise specified.

Species	Freezing Point Depression °C	Osmotic Pressure, atm	Conductivity mhos x 10 ⁵	Species	Freezing Point Depression °C	Osmotic Pressure, atm	Conductivity mhos x 10 ⁵
1 Aconite (<i>Aconitum porrectum</i>)	1.1-1.2	13.3-14.6	1560-1750	36 Oak, pin (<i>Quercus palustris</i>), 9 ft high	1.7	20.2	1060
2 Alfalfa (<i>Medicago sativa</i>)	1.4-2.0	16.3-24.1	2040-2940	37 Oak, pin (<i>Q. palustris</i>), 23 ft high	1.7	20.8	1000
3 Apple (<i>Pyrus malus</i>)	2-2.3	24-27	1100-1320	38 Oak, pin (<i>Q. palustris</i>), 33 ft high	1.9	23.2	900
4 Apple (<i>P. malus</i>), twig	1.5-1.7	18-20.6	860-950	39 Orange (<i>Citrus sinensis</i>)	1.4-2.4	15-22.2	1460-1690
5 Apple (<i>P. malus</i>), root	0.9-1.4	9.6-11.4	680-1270	40 Orange (<i>C. sinensis</i>), shoot	1.1-1.7	14.2-20.8	
6 Asparagus (<i>Asparagus officinalis</i>)	1.5-1.6	18.1-19.1	1800-2050	41 Peach (<i>Prunus persica</i>)	2.2-2.9	25-35	1140-1330
7 Barley (<i>Hordeum vulgare</i>)	1.4	17.3	2870	42 Peach (<i>P. persica</i>), twig	1.3-2.2	16.3-25	710-860
8 Bean (<i>Phaseolus</i> sp)	0.9-1.4	11.7	1310	43 Peach (<i>P. persica</i>), root	0.7-0.9	8.7-11.6	260-310
9 Beet (<i>Beta vulgaris</i>)	0.7-1.1	8-13.7	1630-1690	44 Poplar (<i>Populus alba</i>)			
10 Beet (<i>B. vulgaris</i>), root	1.5-1.8	17.7	555	45 Spring leaves	1.3	15.9	910
11 Burroweed (<i>Allenrolfea occidentalis</i>)	3-5.2	36-62	6260-7010	46 Summer leaves	1.5	17.8	650
12 Carrot (<i>Daucus carota</i>)	1.2-1.4	13.2-16.7	1940-2360	47 Stem bark	1.2	14.6	450
13 Coffee (<i>Coffea arabica</i>)	1.3	15.5		48 Stem tracheae	0.05	0.6	34
14 Columbine (<i>Aquilegia caerulea</i>)	1.2	14.3	1530	49 Root bark	1.1	13.2	380
15 Corn (<i>Zea mays</i>)	0.9-1.5	11-18.1	960-2210	50 Root tracheae	0.07	0.9	52
16 Corn (<i>Z. mays</i>), stem	1-1.4	11.8-16.3	960-2160	51 Potato (<i>Solanum tuberosum</i>)	0.4-0.8	5.2-9	
17 Corn (<i>Z. mays</i>), root	0.8-1.1	0.9-12.7	2180-2520	52 Potato (<i>S. tuberosum</i>), stem	0.6-0.9	7.5-11.3	555
18 Cotton (<i>Gossypium barbadense</i>)	1.5-2.2	18.3-27	2950-3160	53 Potato (<i>S. tuberosum</i>), tuber	0.4-0.8	5.4-10.3	
19 Cotton (<i>G. herbaceum</i>)	1.1-1.5	13.2-19	2880-3370	54 Sagebrush (<i>Artemisia tridentata</i>)	2.2-4.2	26-50	1000-2400
20 Cotton (<i>G. hirsutum</i>)	1.2	13.8	2020	55 Saltgrass (<i>Distichlis spicata</i>)	1.6-5	19.8-60	2840-9100
21 Fig (<i>Ficus carica</i>)	1.2	14.6		56 Sawgrass (<i>Cladium effusum</i>)	0.6-1.1	6.8-13.3	
22 Grape (<i>Vitis labrusca</i>)	0.1-1.1	10.7-13	670	57 Sorghum (<i>Sorghum vulgare</i>)	0.9-1.1	10.7-13.4	1500-1780
23 Grapefruit (<i>Citrus paradisi</i>)	1.5	17.9	1390	58 Sorghum (<i>S. vulgare</i>), stem	1.2-1.6	14.3-19.7	840-2220
24 Greasewood (<i>Sarcobatus vermiculatus</i>)	2-3	25-37	4700-6700	59 Sorghum (<i>S. vulgare</i>), root	1.1-1.8	12.5-21.9	1800-2600
25 Lemon (<i>Citrus limonia</i>)	1.2-2.0	14.4-23.9	1320-1720	60 Spanish moss (<i>Tillandsia usneoides</i>)	0.5-0.9	6-10.4	
26 Lemon (<i>C. limonia</i>), shoot	1.1-1.8	12.8-21.3		61 Strawberry (<i>Fragaria</i> sp)	2.2	26.8	1750
27 Lime (<i>C. aurantifolia</i>)	1.3-1.6	16.1-19	1480-1490	62 Sunflower (<i>Helianthus annuus</i>), in Arizona	1.4	16.4	2650
28 Mangrove (<i>Rhizophora mangle</i>)	2.5	30		63 Sunflower (<i>H. annuus</i>), in Florida	0.7	8.6	1690
29 Maple (<i>Acer grandidentatum</i>), in Utah	1.1-2.2	12.5-27	1030-1690	64 Sweetclover (<i>Melilotus alba</i>)	1.1-1.7	12.9-20.6	1310-1790
30 Maple (<i>A. grandidentatum</i>), in Florida		30	860	65 Sweetpotato (<i>Ipomoea batatas</i>)	0.9	9.5	1890
31 Maple, red (<i>A. rubrum</i>), 12 ft high	1.3	16	940	66 Tomato (<i>Lycopersicon esculentum</i>)	0.8	8.2	
32 Maple, red (<i>A. rubrum</i>), 27 ft high	1.4	16.4	910	67 Tomato (<i>L. esculentum</i>), root	0.4-1.3	5-15.9	
33 Maple, red (<i>A. rubrum</i>), 47 ft high	1.4	16.7	860	68 Wheat (<i>Triticum aestivum</i>), entire plant	0.8-2.4	9.6-28	1370-2950
34 Mistletoe (<i>Phoradendron juniperinum</i>)	2-2.5	25-30	1960-2370				
35 (Host: Juniper (<i>Juniperus utahensis</i>))	1.4-2.3	17.5-28	940-1490				

60. XYLEM AND PHLOEM EXUDATION: SQUASH, PUMPKIN

Part I: XYLEM EXUDATION: SQUASH				
Period	Total Sap ml	Rate of Flow ml/plant/min	Dry Matter g/100g	Temp °C
1 9:15-9:30 A. M.	10.5	0.17	0.16	26.5
2 9:30-9:45 A. M.	28.0	0.47	0.16	
3 9:45-10:00 A. M.	30.0	0.50	0.16	
4 10:00-10:10 A. M.	24.5	0.61	0.15	
5 10:10-10:15 A. M.	10.2	0.51	0.13	
6 10:15-10:20 A. M.	12.5	0.62	0.16	
7 10:20-10:25 A. M.	12.0	0.60	0.18	
8 10:25-10:30 A. M.	12.5	0.62	0.18	
9 10:30-10:35 A. M.	12.5	0.62	0.19	
10 10:35-10:40 A. M.	11.5	0.57	0.22	
11 10:40-10:45 A. M.	10.5	0.52	0.18	30
12 10:45-10:50 A. M.	11.0	0.55	0.19	
13 10:50-10:55 A. M.	10.0	0.50	0.20	
14 10:55-11:00 A. M.	8.5	0.42	0.23	
15 11:00-11:05 A. M.	9.5	0.47	0.21	

/1/ Values applicable to greenhouse. Temp of culture solution, 25°C.

Part II: PHLOEM EXUDATION: SQUASH						
Period	Total Sap		Phloem Area sq cm	Rate of Flow ² cm/hr	Temp °C	
	Fresh Weight g	Dry Weight ¹ g				
1 2:00-3:00 P. M.	0.788	0.055 (6.9)	0.044	17.9	26.0	
2 3:00-4:00 P. M.	0.852	0.042 (4.9)	0.059	14.4	27.0	
3 4:00-5:00 P. M.	0.710	0.032 (4.5)	0.060	11.8	22.5	
4 5:00-6:00 P. M.	0.596	0.026 (4.4)	0.060	9.9	30.0	
5 6:00-7:00 P. M.	0.437	0.019 (4.3)	0.073	6.0	26.0	
6 7:00-8:00 P. M.	0.321	0.016 (5.0)	0.077	4.2	21.0	
7 8:00-9:00 P. M.	0.499	0.020 (4.1)	0.077	6.5	24.0	
8 9:00-10:00 P. M.	0.671	0.024 (3.6)	0.077	8.7	23.5	
9 10:00-11:00 P. M.	0.725	0.023 (3.1)	0.084	8.6	24.5	
10 11:00-12:00 P. M.	0.584	0.019 (3.3)	0.087	6.7	23.0	
11 12:00-1:00 A. M.	0.586	0.018 (3.2)	0.082	7.1	23.5	
12 1:00-2:00 A. M.	0.689	0.021 (3.0)	0.082	8.4	25.0	

/1/ Dry weight as percentage of fresh weight is enclosed in parentheses. /2/ Determinations based on cross-sectional area of total phloem. Because sieve tubes occupy approximately 25% of the phloem, values must be multiplied by 4 to obtain actual rates.

Part III: COMPOSITION OF PHLOEM EXUDATE FROM FRUITS: PUMPKIN									
Phloem Exudate					Fruits				
Fruit Size ¹	Carbon g/100g	Nitrogen g/100g	Ash g/100g	C:N	Dry Matter g/100g	Fruit Size ¹	Carbon g/100g	Nitrogen g/100g	Dry Matter g/100g
1 A	45	13.2	9.7	3.4	9.4	4 A	43	3.5	10.9
2 B	44	13.1	8.7	3.4	9.7	5 B	38	2.5	10.1
3 C	44	13.2	9.1	3.4	10.5	6 C	37	2.6	10.1

/1/ Fruit A: length, 10 cm; greatest diameter, 2.7 cm; weight, 43 g. Fruit B: length, 21 cm; greatest diameter, 5.7 cm; weight, 344 g. Fruit C: length 27 cm; greatest diameter, 7.6 cm; weight, 894 g.

61. CELL SAP: pH VALUES
Data applicable to sap of leaves except as otherwise specified.

Species		pH	Species		pH
1 Aconite (Aconitum porrectum)		5	24 Oat (Avena sativa), entire plant		5.6-5.7
2 Alfalfa (Medicago sativa)		5.3	25 Olive (Olea europaea), shoot		5.2
3 Apple (Pyrus malus), twig		5.4-6	26 Onion (Allium cepa)		4.3
4 Apple (P. malus), fruit		3.4	27 Orange (Citrus sinensis)		5.8
5 Asparagus (Asparagus officinalis)		5.8	28 Orange (C. sinensis), shoot		5.3-6.2
6 Banana (Musa paradisiaca sapientum), midrib		4.7	29 Orange (C. sinensis), fruit		3.6
7 Barley (Hordeum vulgare)		6	30 Oxalis (Oxalis sp)		1.7-2.1
8 Bean (Phaseolus sp)		5.9-6.1	31 Pineapple (Ananas sativus)		4.7
9 Beet, sugar (Beta vulgaris)		6	32 Pineapple (A. sativus), fruit		4.4
10 Begonia (Begonia lucerna)		0.9-1.4	33 Potato (Solanum tuberosum), tuber		5.6
11 Boston fern (Nephrolepis exaltata bost.)		5.2	34 Rape (Brassica napus)		6-6.4
12 Buckwheat (Fagopyrum esculentum)		5.5-5.9	35 Rhubarb (B. campestris napo-brassica), petiole		3.6
13 Buckwheat (F. esculentum), stem		4.7-5	36 Sorghum (Sorghum vulgare), entire plant		5.4-5.7
14 Burroweed (Allenrolfea occidentalis)		5.9-6.6	37 Soybean (Glycine soja)		5.8-6.2
15 Columbine (Aquilegia caerulea)		4.6-5.3	38 Soybean (G. soja), stem		5.7-5.8
16 Corn (Zea mays)		5-5.6	39 Soybean (G. soja), root		6.3-6.6
17 Corn (Z. mays), stem		5.3-5.7 ¹	40 Sugarcane (Saccharum officinarum)		5.5-5.7
18 Cotton (Gossypium herbaceum)		5.1-6.8	41 Sugarcane (S. officinarum), stem		5.5-6.6
19 Cranberry (Vaccinium sp), fruit		2.4	42 Sunflower (Helianthus annuus)		6.3-6.9
20 Garlic (Allium sativum), bulb		3.5	43 Tobacco (Nicotiana tabacum)		5.3-5.8
21 Grapefruit (Citrus paridisi), fruit		3	44 Tomato (Lycopersicon esculentum)		5.3-5.8
22 Lemon (C. limonia), shoot		5.1-6.1	45 Wheat (Triticum aestivum), entire plant		5.6-6.1
23 Milo (Sorghum vulgare durra)		4.7			

/1/ Exuded sap not expressed under pressure, 4.3-4.7.

62. CELL SAP: CHEMICAL COMPOSITION

Species		Plant Part	Growth Stage	Value mg/100g	Species		Plant Part	Growth Stage	Value mg/100g
Calcium					Phosphorus (concluded)				
1 Bean, field (Phaseolus sp)	Leaf	Mature	515-690	50 Beet, sugar (Beta vulgaris)	Stem	Mature	4.5-24.2		
2 Alfalfa (Medicago sativa)	Stem	Mature	137-283	51 Buckwheat (Fagopyrum esculentum)	Leaf		22-105		
3 Corn (Zea mays)	Stem		4.7-11.6	52	Stem		24-145		
4 Peanut (Arachis hypogaea)	Lower leaf	Immature	500	53 Cabbage (Brassica oleracea cap.)	Lower leaf	Immature	0.02-1.7		
5 Potato (Solanum tuberosum)	Lower stem	Mature	100	54 Carrot (Daucus carota)	Root	2-3 mo old	0.04-1.0		
6 Rye (Secale cereale)	Entire plant		52-59	55 Celery (Apium graveolens)	Leaf	Mature	8.8-17.9		
7 Tomato (Lycopersicon esculentum)	Stem	Immature	18	56	Stem	Mature	6-22.8		
8 Wheat (Triticum aestivum)	Shoot	Mature	68-106	57 Clover (Trifolium pratense)	Entire plant	82 da old	7.7-21.2		
9	Entire plant	Immature	43	58 Collard (Brassica oleracea aceph.)	Stem		5.8-7.6		
Magnesium					59 Corn (Zea mays)	Lower stem	Mature	2.7-3.8	
10 Bean, field (Phaseolus sp)	Leaf	Mature	42-109	60	Entire plant	Mature	1.6-12.2		
11	Stem	Mature	76-105	61 Fescue (Festuca elatior)	Entire plant	Immature	0.5		
12 Beet, sugar (Beta vulgaris)	Leaf	Mature	80-200	62	Petiole		1.2-4.4		
13	Stem	Mature	70-130	63	Lower leaf	Immature	2.3		
14 Cabbage (Brassica oleracea cap.)	Stem		6	64	Lower stem	Mature	6		
15 Collard (B. oleracea acephala)	Stem		2.4-7.8	65 Rape (Brassica napus)	Leaf	Immature	15-86		
16 Pea, black (Pisum sp)	Petiole		19-42	66 Rye (Secale cereale)	Entire plant	Immature	82-112		
17 Peanut (Arachis hypogaea)	Lower leaf		290	67 Sorghum (Sorghum vulgare)	Entire plant		90-116		
18 Rye (Secale cereale)	Entire plant	Immature	14-88	68 Soybean (Glycine soja)	Entire plant	Fruiting	2.6-9.0		
19 Tomato (Lycopersicon esculentum)	Stem		6-41	69 Sugarcane (Saccharum officinarum)	Stem	Mature	11-19		
20 Wheat (Triticum aestivum)	Shoot		27-107	70 Tomato (Lycopersicon esculentum)	Petiole	Fruiting	30		
21	Entire plant	Immature	39	71	Stem	Immature	12.5-20		
Nitrogen as NO ₃					72	Shoot	Immature	9.7-19.2	
22 Barley (Hordeum vulgare)	Leaf	Mature	20	73 Turnip (Brassica rapus)	Root		0-3.4		
23	Stem	Mature	23	74 Wheat (Triticum aestivum)	Shoot	Immature	35-81		
24 Beet, garden (Beta vulgaris)	Leaf	44-79 da old	3-52	75	Entire plant	Immature	80		
25 Buckwheat (Fagopyrum esculentum)	Shoot		12.6-17.2	Potassium					
26 Cabbage (Brassica oleracea cap.)	Lower leaf	Immature	13-55	76 Barley (Hordeum vulgare)	Leaf	Mature	310-860		
27	Stem	Immature	54	77	Stem	Mature	260-800		
28 Carrot (Daucus carota)	Root	2-3 mo old	3-32	78	Entire plant	36 da old	250		
29 Celery (Apium graveolens)	Leaf		18-52	79 Bean, field (Phaseolus sp)	Leaf	Mature	28-200		
30 Collard (Brassica oleracea aceph.)	Stem		13-64	80 Beet, sugar (Beta vulgaris)	Leaf	Mature	97-516		
31 Corn (Zea mays)	Lower stem	Mature	8-41	81	Stem	Mature	340-414		
32	Entire plant	Mature	0.5-25	82	Lower leaf	Immature	112-455		
33 Fescue (Festuca elatior)	Entire plant	Immature	1.8	83 Celery (Apium graveolens)	Leaf	Mature	239-418		
34 Lettuce (Lactuca sativa)	Leaf	Mature	6-45	84	Stalk	Mature	255-408		
35 Oat (Avena sativa)	Stem	Mature	41	85	Entire plant	82 da old	44-234		
36 Pea, black (Pisum sp)	Petiole		2-22	86 Collard (Brassica oleracea aceph.)	Stem		160-415		
37 Potato (Solanum tuberosum)	Lower stem		16.1-18.4	87	Lower stem	Mature	166		
38 Rye (Secale cereale)	Entire plant	Immature	3.8-12.4	88	Entire plant		390-650		
39 Soybean (Glycine soja)	Entire plant	Fruiting	2.4-3.6	89 Parsnip (Pastinaca sativa)	Root	3-4 mo old	142-353		
40 Sugar cane (Saccharum officinarum)	Stem	Mature	10-40 ²	90	Petiole		250-415		
41 Tomato (Lycopersicon esculentum)	Petiole	Fruiting	6.9	91	Lower leaf	Immature	500		
42	Stem	Immature	5.8-11.5	92	Lower stem	Mature	254-621		
43 Wheat (Triticum aestivum)	Shoot	Mature	1-58	93 Rye (Secale cereale)	Entire plant	Immature	579		
44	Entire plant	Immature	2.8	94	Entire plant	Fruiting	96-885		
Phosphorus					95 Sugarcane (Saccharum officinarum)	Stem	Mature	128-266	
45 Barley (Hordeum vulgare)	Leaf	Mature	6.4-56	96 Tomato (Lycopersicon esculentum)	Stem	Immature	200-300		
46	Stem	Mature	8.9-78	97 Turnip (Brassica rapus)	Leaf		92-425		
47	Entire plant	36 da old	10	98	Root		199-343		
48 Bean, field (Phaseolus sp)	Leaf	Mature	3.5-17.7	99	Entire plant	Immature	411		
49 Beet, sugar (Beta vulgaris)	Leaf	Mature	10.5-250						

/1/ Values are NO₃-N except as otherwise specified. /2/ Total nitrogen.

63. SHOOTS, LEAVES, SEEDS: MINERAL COMPOSITION

Values are g/100g or mg/kg of specified dry weight material.

Species		K	P	Ca	Mg	S	B	Cu	Fe	Mn	Zn
		g/100g					mg/kg				
Shoots											
Pandanaceae; Helobiae											
1	Cattail (<i>Typha angustifolia</i>)	2.0	0.16	1.5	0.1	0.10					
2	Elodea (<i>Elodea canadensis</i>)	1.5-3.0	0.28-0.74	2.9-8.2	0.5-1.2	0.15-0.97					
3	Plantain (<i>Alisma plantago-aquatica</i>)	1.8	0.24	1.0	0.3	0.39					
Glumiflorae											
4	Barley (<i>Hordeum vulgare</i>)	3.9	0.35	0.7	0.2	0.19	4-53	14	180-540		
5	Bentgrass (<i>Agrostis tenuis</i>)	1.1-3.8	0.15-0.17	0.2-0.9	0.1					296	
6	Bermudagrass (<i>Cynodon dactylon</i>)	1.1-3.0	0.18-0.27	0.4-0.5	0.1-0.3	0.36-0.50	4		150		
7	Bluegrass (<i>Poa pratensis</i>)	1.4-4.3	0.19-0.95	0.1-1.2	0.1-0.2	0.06-0.66	6-12		60-425	29-216	17-28
8	Broomsedge (<i>Andropogon virginicus</i>)	1.2	0.08-0.23	0.3	0.1	0.07					
9	Crabgrass (<i>Digitaria sanguinalis</i>)	3.7	0.30	0.3	0.5	0.17					
10	Fescue (<i>Festuca elatior</i>)	2.4-4.0	0.24-0.37	0.5-0.9	0.1-0.3	0.08-0.17					
11	Johnsongrass (<i>Sorghum halepense</i>)	1.6	0.22	0.4	0.2	0.06					
12	Orchardgrass (<i>Dactylis glomerata</i>)	1.6-4.5	0.19-0.58	0.3-0.8	0.1-0.3	0.06-0.27	5-18			120-370	
13	Redtop (<i>Agrostis alba</i>)	0.7-4.2	0.05-0.41	0.1-1.0	0.1-0.3	0.08-0.33		3-5	56-160	79-510	10-60
14	Rescuegrass (<i>Bromus catharticus</i>)	3.7	0.30	0.2	0.2	0.18		6			14
15	Rye (<i>Secale cereale</i>)		0.23	0.3			0.3-3	7-8			20-21
16	Ryegrass (<i>Lolium perenne</i>)	2.2-4.9	0.28-0.30	0.5-0.9	0.2	0.2	2.9		880		
17	Sedge (<i>Carex acuta</i>)	0.9-1.2	0.12	0.2-1.7	0.1-0.2	0.02-0.13	5 ¹		350-680 ¹		
18	Sudangrass (<i>Sorghum vulgare</i> sud.)	0.4-2.5	0.16-0.40	0.4-1.2	0.3-0.8	0.05		10	70-140		
19	Timothy (<i>Phleum pratense</i>)	0.8-3.8	0.08-0.60	0.04-1.2	0.03-0.04	0.07-0.32	10-16	2-7	30-287	11-165	30-60
20	Wheat (<i>Triticum aestivum</i>)	2.8	0.32	0.8	0.1	0.11	3-10	3-12	290-580		13-25
21	Velvetgrass (<i>Holcus lanatus</i>)	2.0	0.22	0.4	0.1	0.28	7		140		25
Spathiflorae; Liliiflorae											
22	Cuckoo-pint (<i>Arum maculatum</i>)	1.4	0.28	2.1	0.5	0.2	9		1620		
23	Asparagus (<i>Asparagus officinalis</i>)	1.4-3.4	0.14-0.78	0.2-1.4	0.1-0.2	0.13-0.26	9-244	7-17	60-979	12-29	52
24	Onion (<i>Allium cepa</i>)	2.6	0.19	2.6	0.3	0.18	4-44				
Polygonales; Centrospermae											
25	Buckwheat (<i>Fagopyrum esculentum</i>)	1.7-2.6	0.13-0.54	1.7-2.6	0.4-0.6	0.10-0.11	26 ²		100	14	15
26	Sorrell, sheep (<i>Rumex acetosella</i>)	1.4-1.9	0.40-0.49	1.2-2.9	0.5-0.7	0.12					
27	Chickweed (<i>Stellaria media</i>)	3.7	0.40	1.32	1.7	0.14					
28	Corn cockle (<i>Agrostemma githago</i>)	3.1	0.44	2.8	0.5	0.13					
29	Lamb's-quarters (<i>Chenopodium album</i>)	3.5	0.36	2.1	0.4	0.15			158 ³		
30	Purslane (<i>Portulaca oleracea</i>)	10.8	0.48	1.6	1.2	0.27					
31	Saltbush (<i>Atriplex canescens</i>)	0.8	0.05	0.7	0.4	0.28					
Rhoeadales; Rosales											
32	Celandine (<i>Chelidonium majus</i>)	2.0	0.48	1.5	0.2	0.06	17				
33	Mustard (<i>Brassica hirta</i>)	3.1	0.40	1.8	0.3	0.60	13-54		350		
34	Alfalfa (<i>Medicago sativa</i>)	0.7-4.0	0.15-0.71	0.6-3.5	0.1-1.0	0.19-0.40	12-128	4-61	110-675	10-124	13-112
35	Broadbean (<i>Vicia faba</i>)	2.1	0.27	0.9	0.2	0.14			280	36	
36	Clover (<i>Trifolium incarnatum</i>)	0.7-5.9	0.08-0.53	1.0-1.8	0.2-0.4	0.06-0.40	70		470-1400	24-387	
37	Lespedeza (<i>Lespedeza</i> spp)	1.2-1.4	0.13-0.30	1.0-1.2	0.2-0.3		18-20		126-1028	54-331	
38	Pea, garden (<i>Pisum sativum</i>)	1.7	0.34	1.5	0.5	0.33	17-22			15	
39	Soybean (<i>Glycine soja</i>)	0.5-2.3	0.09-0.74	0.5-2.2	0.2-0.9	0.12-0.52	1-13	4-12	100-570	45-280	28-80
40	Vetch (<i>Vicia sativa</i>)	2.1-2.3	0.33-0.44	1.6-2.0	0.3-0.5	0.27-0.28		10 ¹		14-360 ¹	
Malvales; Tubiflorae											
41	Carrot (<i>Daucus carota</i>)	2.4-3.4	0.20-0.29	1.3-3.3	0.2-0.4	0.07-0.48	20-45	5-10	355-765	23-199	26
42	Cotton (<i>Gossypium</i> spp)	0.9-2.1	0.23-0.43	1.0-2.2	0.1-0.7	0.26-0.33	60-795 ³		1754 ³	80-100 ³	
43	Bindweed (<i>Convolvulus arvensis</i>)	2.5	0.77	2.0	0.5	0.19					
44	Bugleweed (<i>Ajuga reptans</i>)	2.4-3.5	0.23-0.76	0.2-1.8	0.3-0.7	0.14-0.43	16		1000-2030		
45	Dodder (<i>Cuscuta europaea</i>)	3.7	0.54	0.2	0.1	1.0					
46	Horsenettle (<i>Solanum carolinense</i>)	1.9	0.98	1.3	1.0	0.48					
47	Mullein (<i>Verbascum thapsus</i>)	3.0	0.19	1.0	0.2	0.21					
48	Peppermint (<i>Mentha piperita</i>)	1.5-2.6	0.19-0.31	0.7-1.9				8-12			
49	Potato (<i>Solanum tuberosum</i>)	0.03-4.2	0.08-0.26	0.6-4.1	0.2-1.2	0.15-0.68	14-39	11		86-108	
Plantaginales; Campanulatae											
50	Plantain (<i>Plantago lanceolata</i>)	2.6	0.27	1.2	0.2	0.33					
51	Bellflower (<i>Campanula patula</i>)	2.4	0.25	0.8	0.3	0.16					
52	Dandelion (<i>Taraxacum officinale</i>)	4.4	0.49	1.0	0.3	0.22	14	13 ³	440	19 ³	98-101 ³
53	Ragweed (<i>Ambrosia artemisiifolia</i>)	1.9	0.25	1.8	0.5	0.23			190		17-65
Leaves											
Glumiflorae; Principes											
54	Sugar cane (<i>Saccharum officinarum</i>)	0.4-2.5	0.07-0.98	0.1-0.6	0.04-0.6	0.06-0.23			370	30	
55	Date (<i>Phoenix dactylifera</i>)	0.2-1.6	0.06-0.19	0.3-1.1	0.1-0.2		73-172				
Salicales; Juglandales											
56	Aspen, European (<i>Populus tremula</i>)	1.4	0.34	3.1	0.2	0.10					
57	Pecan (<i>Carya illinoensis</i>)	0.3-0.9	0.10-0.15	1.1-1.6	0.4			21-28	144-185		4-202
58	Walnut, black (<i>Juglans nigra</i>)	2.0-2.4	0.32-0.54	1.1-3.2	0.4-0.5	0.01-0.23	40-67	11	280-780	60-190	26-49
Fagales; Urticales											
59	Hornbeam (<i>Carpinus betulus</i>)	0.5	0.2	2.3	0.1	0.04					
60	Oak, black (<i>Quercus velutina</i>)	1.0-1.2	0.15-0.20	0.9-2.2	0.3-0.4	0.04-0.25		7-9	250-280	490-1870	38-68
61	Elm, American (<i>Ulmus americana</i>)	0.6-2.0	0.13-0.59	1.4-2.4	0.4-0.6	0.02-0.35	277	7-16	245-810	39-130	10-22
62	Fig (<i>Ficus carica</i>)	1.0	0.21	2.2	0.7	0.08	245-1349				
63	Hackberry (<i>Celtis occidentalis</i>)	1.7-2.3	0.16-0.44	2.5-7.8	0.4-0.5	0.17-0.29		6-8	550-730	100-170	6-32
64	Mulberry, red (<i>Morus rubra</i>)	2.3	0.29	3.8	0.4	0.09		7	500	250	30
65	Nettle (<i>Urtica dioica</i>)	2.2	0.80	4.6	0.9	0.76					
66	Ramie (<i>Boehmeria</i> spp)	0.7	0.41	4.9	0.8	0.15					
Santalales; Ranales											
67	Mistletoe (<i>Viscum album</i>)	0.1-2.3	0.25-0.77	0.9-1.7	0.3-0.7	0.08-0.26					
68	Magnolia, bigleaf (<i>Magnolia macrophylla</i>)	1.2-3.3	0.18-0.48	0.1-2.4	0.3-0.4	0.02-0.29		6-8	150-230	29-30	19-62
69	Waterlily (<i>Nymphaea alba</i>)	1.1-1.6	0.15-0.22	1.8-2.2	0.2-0.3	0.06-0.07					
70	Yellow-poplar (<i>Liriodendron tulipifera</i>)	0.9-1.7	0.20-0.36	1.0-3.5	0.2-0.3	0.26-0.38		3-5	240-380	40-90	26-68

/1/ Applicable to various species. /2/ Applicable to stems. /3/ Applicable to leaves.

63. SHOOTS, LEAVES, SEEDS: MINERAL COMPOSITION (Concluded)

Values are g/100g or mg/kg of specified dry weight material.

Species		K	P	Ca	Mg	S	B	Cu	Fe	Mn	Zn
		g/100g					mg/kg				
Leaves (concluded)											
	Rosales	0.5-3.9	0.09-0.75	0.6-2.7	0.1-0.8		11-43	3-12	65-507	20-156	4-345
71	Apple (<i>Pyrus malus</i>)	1.2-2.1	0.20-0.56	1.5-4.5	0.3-0.4	0.02-0.39	30-70	7	190-330	40-50	7-50
72	Blacklocust (<i>Robinia pseudoacacia</i>)	1.1-1.3	0.14-0.47	1.3-2.4	0.4-0.6	0.06-0.21	104 ¹	6-8	210-290	170-230	27-72
73	Cherry, black (<i>Prunus serotina</i>)	1.4-1.8	0.34-0.56	1.3-1.9	0.2-0.3	0.16-0.21		8-9	180-300	20-30	7-52
74	Crabapple (<i>Malus coronaria</i>)	0.8-2.4	0.09-0.72	1.1-2.7	0.4-1.4		17-81			17-325	6-345
75	Peach (<i>Prunus persica</i>)	4.2	0.26	2.1	0.7						
76	Peanut (<i>Arachis hypogaea</i>)	0.8-2.2	0.11-0.16	1.2-3.0	0.3-0.4			5-41	28-94		
77	Pear (<i>Pyrus communis</i>)	0.6-1.6	0.17-0.37	0.8-2.0	0.4-0.5	0.01-0.26	19-29	9-15	200-740	310-700	2-27
78	Sweetgum (<i>Liquidambar styraciflua</i>)	1.2-1.6	0.15-0.46	1.4-2.2	0.3	0.08-0.42		4-7	180-260	120-150	9-42
79	Sycamore (<i>Platanus occidentalis</i>)	1.8-2.4	0.42-0.78	1.8-3.7	0.2-0.3	0.11-0.25		7-12	180-360	30-70	11-40
80	Yellow-wood (<i>Cladrastis lutea</i>)	Geraniales; Sapindales; Rhamnales									
	Geraniales; Sapindales; Rhamnales	1.3-2.3	0.34-0.45	0.9-1.2	0.3-0.6	0.15-0.38	7-24 ⁴	3-4 ⁴			20-28 ⁴
81	Flax (<i>Linum usitatissimum</i>)	0.7-2.0	0.07-0.40	0.5-1.1	0.3-0.5	0.21-0.33		6-14	200-270	260-540	130-240
82	Holly, American (<i>Ilex opaca</i>)	1.0-1.6	0.24-0.46	0.6-2.4	0.2-0.4	0.01-0.24		11-12	150-440	40-220	24-54
83	Maple, sugar (<i>Acer saccharum</i>)	0.6-2.9	0.13-0.50	0.6-4.9	0.2-0.6		15-125	4-15	41-375	22-288 ⁴	16-229
84	Tung (<i>Aleurites fordii</i>)	0.9-2.6	0.28-0.61	1.6-4.4	0.3-0.5	0.15-0.31		5-7	340-500	70-120	28-35
85	Buckeye, Ohio (<i>Aesculus glabra</i>)	0.6-1.0	0.08-0.20	1.8-2.8	0.2-0.4	0.10-0.11	16-208 ⁴	3-47 ¹	190-220 ¹	180-220 ¹	
86	Grape, riverbank (<i>Vitis vinifera</i>)	Malvales; Umbelliflorae; Ebenales									
	Malvales; Umbelliflorae; Ebenales	1.1-2.5	0.22-0.62	1.4-6.4	0.4-0.8	Tr-0.34		8-10	220-430	7-210	21-54
87	Basswood, American (<i>Tilia americana</i>)	0.4-1.1	0.18-0.32	2.7-4.2	0.3-0.5	0.38-0.70	23	7-9	240-380	30-50	3-28
88	Dogwood, flowering (<i>Cornus florida</i>)	1.0	0.26	3.6	0.2	0.28					
89	Ivy, English (<i>Hedera helix</i>)	2.0-2.4	0.14-0.46	0.6-1.8	0.3-0.5	0.27-0.28		5-8	210-250	90-220	36-48
90	Persimmon (<i>Diospyros virginiana</i>)	Oleales; Tubiflorae									
	Oleales; Tubiflorae	1.3-2.0	0.35-0.61	0.6-2.0	0.3-0.4	0.11-0.39		11-16	250-330	60-80	12-34
91	Ash, blue (<i>Fraxinus quadrangulata</i>)	0.9-1.0	0.20-0.54	0.5	0.2	0.01-0.05	4-8 ¹		110-700 ¹		
92	Lilac (<i>Syringa vulgaris</i>)	0.5-1.1	0.12-0.30	0.8-1.9	0.1-0.2	0.02-0.05	7-44		250-880		
93	Olive (<i>Olea europaea</i>)	2.8	0.37	1.2	0.4	0.26					
94	Belladonna (<i>Atropa belladonna</i>)	1.3-2.5	0.30-0.58	1.2-2.3	0.3-0.5	0.22-0.48		18-21	330-680	80-130	28-50
95	Catalpa (<i>Catalpa speciosa</i>)	1.6-2.4	0.19-0.28	0.7-1.2	0.4-0.5						
96	Sweetpotato (<i>Ipomoea batatas</i>)	Rubiales; Campamilatae									
	Rubiales; Campamilatae	0.8-1.2	0.20-0.49	0.4-0.7	0.2-0.3						
97	Cinchona (<i>Cinchona ledgeriana</i>)	2.7	0.16	0.9	0.2	0.08					
98	Coffee (<i>Coffea arabica</i>)	3.5	0.16	2.5	0.3	0.25					
99	Aster (<i>Aster amellus</i>)	4.0-7.7	0.30-0.36	2.4-5.1	0.8-1.4	1.46-1.65					
100	Guayule (<i>Parthenium argentatum</i>)	Seeds									
	Glumiflorae; Fagales	0.3-0.9	0.15-0.62	0.01-0.2	0.02-0.3	0.02-0.37	0.6-13	1-70	14-350	7-38	21-132
101	Barley (<i>Hordeum vulgare</i>)	0.7	0.85	0.3	0.2	0.20		60	350-460	85-110	360
102	Bluegrass, Kentucky (<i>Poa pratensis</i>)	0.3	0.29	0.02	0.2	0.003					
103	Millet (<i>Panicum miliaceum</i>)	0.2-0.5	0.19-0.43	0.05-0.1	0.1-0.2	0.001-0.14	9.4	3-4	76-350	18-70	30
104	Rice (<i>Oryza sativa</i>)	0.5-0.6	0.21-0.52	0.04-0.2	0.1-0.2	0.01-0.41	2-9	2-7	57-700	32-157	13-73
105	Rye (<i>Secale cereale</i>)	0.5	0.54	0.5	0.2	0.31					
106	Ryegrass (<i>Lolium italicum</i>)	0.3	0.29-0.41	0.01-0.1	0.2	0.01					
107	Sorgho (<i>Sorghum vulgare</i>)	0.5	0.35	0.2	0.1	0.03			61-410	72	
108	Timothy (<i>Phleum pratense</i>)	0.2-1.0	0.15-0.54	0.01-0.30	0.1-0.3	0.003-0.29	1.11	3-24	3-420	5-260	19-105
109	Wheat (<i>Triticum aestivum</i>)	1.0-1.2	0.44-0.49	0.3-0.5	0.2-0.3	0.08-0.09					
110	Beech, European (<i>Fagus sylvatica</i>)	0.7	0.17	0.1	0.1	0.09					
111	Chestnut (<i>Castanea sativa</i>)	Centrospermae; Ranales; Rhoeadales									
	Centrospermae; Ranales; Rhoeadales	1.0	0.44	0.9	0.5	0.10					
112	Beet (<i>Beta vulgaris</i>)	1.4	0.73	0.2	0.2						
113	Waterlily (<i>Nymphaea tetragona</i>)	0.6	0.73	0.6	0.2	0.08	12		290		
114	Mustard (<i>Brassica hirta</i>)	0.5-0.7	0.82-0.89	1.3-1.6	0.3-0.4	0.05-0.10					
115	Poppy, opium (<i>Papaver somniferum</i>)	0.7	0.87	0.6	0.1	0.07					
116	Radish (<i>Raphanus raphanistrum</i>)	0.9	0.82	0.4	0.3	0.04	11		85-480	38	
117	Rape (<i>Brassica napus</i>)	Rosales; Geraniales									
	Rosales; Geraniales	0.8	0.71	0.2	0.4	0.05					
118	Apple (<i>Pyrus malus</i>)	0.2-1.1	0.44-0.93	0.2-0.3	0.2-0.5	0.01-0.05	15-57	11-13	42-190	13	21
119	Almond (<i>Prunus amygdalus</i>)	1.2-1.9	0.41-0.50	0.1-0.2	0.15-0.20	0.05-0.23	17		120	20	
120	Bean (<i>Phaseolus vulgaris</i>)	0.6-1.2	0.31-0.58	0.3-0.6	0.2	0.02					
121	Bean, mung (<i>P. aureus</i>)	1.2-1.3	0.58-0.62	0.1	0.1-0.2	0.05-0.09	11-223	10-11	21	14-15	
122	Broadbean (<i>Vicia faba</i>)	0.7	0.57	0.1	0.4	0.04	14	7	560	29	19
123	Chick pea (<i>Cicer arietinum</i>)	1.3-1.8	0.36-0.74	0.1-0.2	0.2-0.3	0.28		5-7	67-662	45	
124	Cowpea (<i>Vigna sinensis</i>)	0.8	0.48	0.2	0.2	0.12			210	678	
125	Lupine (<i>Lupinus spp</i>)	0.8-1.0	0.38-0.61	0.06-0.11	0.1-0.2	0.04-0.16	2-8	6-15	70-282	4-25	40-48
126	Pea, garden (<i>Pisum sativum</i>)	0.9	0.62	0.2	0.4	0.12					
127	Plum (<i>Prunus domestica</i>)	0.8-2.4	0.50-1.80	0.1-0.3	0.2-0.3	0.002-0.45	6-41	12-23	57-161	14-41	18
128	Soybean (<i>Glycine soja</i>)	0.8-1.1	0.50-0.53	0.1-0.2	0.2	0.04-0.14				14-72 ¹	
129	Vetch (<i>Vicia sativa</i>)	0.6-0.9	0.43-0.85	0.2-0.3	0.3-0.4	0.03-0.06	11-17		85-118	38-102	20
130	Flax (<i>Linum usitatissimum</i>)	0.9-1.0	0.29-0.45	0.4-0.5	0.1-0.2						
131	Orange (<i>Citrus aurantium</i>)	Rhamnales; Malvales; Opuntiales									
	Rhamnales; Malvales; Opuntiales	0.6-0.7	0.33-0.34	0.4-0.7	0.1	0.04-0.07					
132	Grape, riverbank (<i>Vitis vinifera</i>)	0.9	0.53	0.1	0.2	0.04					
133	Cocoa (<i>Theobroma cacao</i>)	0.9-1.9	0.48-1.79	0.1-0.3	0.2-0.4	0.05-0.76	27-130 ¹	54 ¹	150-590 ¹	13-31 ¹	320 ¹
134	Cotton (<i>Gossypium hirsutum</i>)	0.2	0.003	0.5	0.2	0.001					
135	Prickly pear (<i>Opuntia compressa</i>)	Oleales; Tubiflorae									
	Oleales; Tubiflorae	0.7	0.38	0.1	0.02	0.03	3				
136	Olive (<i>Olea europaea</i>)	0.5	0.66	1.2	0.4	0.02					
137	Sesame (<i>Sesamum indicum</i>)	1.3	0.62	0.2	0.3	0.02	6 ¹		240 ¹	70 ¹	
138	Tobacco (<i>Nicotiana tabacum</i>)	Rubiales; Cucurbitales									
	Rubiales; Cucurbitales	1.7-1.9	0.22-0.38	0.1-0.2	0.2	0.05-0.06	8-17	8-20	150-280	14-32	
139	Coffee (<i>Coffea arabica</i>)	0.7	0.48	0.04	0.1	0.03					
140	Watermelon (<i>Citrullus vulgaris</i>)										

/1/ Applicable to various species. /4/ Applicable to shoots.

64. PLANT TISSUES AND ORGANS: MINERAL COMPOSITION

Values are g/100 g or mg/kg dry weight material, as specified in column headings.

Values are g/100 g or mg/kg dry weight material, as specified in column headings.												
Species		Plant Part ¹	K	P	Ca	Mg	S	B	Cu	Fe	Mn	Zn
			g/100 g					mg/kg				
1	Carnation	Leaves	1.4	0.21	0.9	0.2	0.08					
2	(<i>Dianthus</i>	Stems	1.0	0.24	1.7	0.2	0.14					
3	<i>caryophyllus</i>)	Roots	1.1	0.28	1.8	0.2	0.06					
4		Petals	2.5	0.36	0.2	0.1	0.09					
5		Leaves	1.8-2.0	0.23-0.34	2.0-2.8	0.5-0.7	0.04-0.05	57			40-84	
6		Petioles	2.6	0.48	2.2	0.6	0.06					
7		Stems	1.7-2.0	0.12-0.32	1.1-1.3	0.4-0.5	0.04-0.06	28			15-20	
8	Clover, red	Shoot, veg.	2.2-3.0	0.32-0.53	1.9-2.0	0.5-0.6	0.09	23-58	6-20 ²	100-1300 ²	25-54 ²	24-80 ²
9	(<i>Trifolium</i>	Shoot, fl.	1.1-3.4	0.21-0.29	1.1-2.1	0.4-0.7	0.09-0.19	19-109			287	
10	<i>pratense</i>)	Shoot, fr.	1.0-1.8	0.23-0.39	1.3-2.0	0.5-0.6	0.06-0.16				465	
11		Flowers	1.5-2.1	0.38-0.50	1.2	0.4-0.5	0.06	40			30-66	
12		Seed	1.3	0.75	0.2	0.4	0.04		17	21-336	6-38	76
13		Leaves	0.2-1.6	0.05-0.26	0.1-0.9	0.2-0.3	0.23-0.25	27-72		41-810	230-440	
14		Stems	0.3-2.4	0.03-0.20	0.1-0.6	0.1-0.3	0.05-0.17			400-740	100-230	
15		Shoot, veg.	6.2-9.9	0.21-0.39	0.6-0.7	0.3	0.32-0.42	15-18 ²	2-9 ³	312-321 ²	52-200 ²	5-80 ³
16		Shoot, fl.	1.7-7.1	0.14-0.55	0.6-0.7	0.2-0.4	0.08-0.37					
17		Shoot, fr.	0.3-1.9	0.04-0.42	0.1-0.8	0.1-0.5	0.08-0.31					
18	Corn	Roots	0.3-1.3	0.03-0.14	0.1-0.7	0.1-0.2	0.03-0.28			500-760	450-880	
19	(<i>Zea mays</i>)	Flowers, ♂	1.3	0.15	0.57	0.27						
20		Flowers, ♀	1.5	0.15	0.63	0.34						
21		Cob	0.5	0.09	0.02	0.1	0.02			250	310	
22		Kernel	0.2-0.9	0.23-0.80	0.01-0.06	0.1-0.3	0.004-0.30	1.9	4-30	13-550	5-500	20
23		Leaves ⁴						60-795		1754	80-100	
24		Stems ⁴						6-186		610	40-50	
25	Cotton	Shoot, veg.	2.6-3.3	0.30-0.33	0.2-2.8	0.5-1.3						
26	(<i>Gossypium</i>	Shoot, fr.	1.0-1.5	0.17-0.20	1.4-1.5	0.4-0.6						
27	<i>hirsutum</i>)	Burs	1.4-5.7	0.07-0.21	0.4-1.0	0.2-0.3						
28		Lint	0.5-0.8	0.02-0.12	0.01-0.27	0.1	0.04-0.06			190	11-190	
29		Seed	0.9-1.9	0.48-1.79	0.1-0.3	0.2-0.4	0.05-0.76	27-130	54	150-590	13-31	320
30		Leaves	3.2	0.82	0.7	0.2	0.08					
31		Petioles	4.3	0.72	1.7	0.2	0.17					
32		Bark	0.5	0.13	2.7	0.05						
33		Wood	0.2	0.07	0.2	0.02						
34	Horsechestnut	Peduncle	5.0	0.70	0.6	0.07	0.13					
35	(<i>Aesculus</i>	Calyx & ovaries	2.7	0.38	0.5	0.2	0.08					
36	<i>hippocastanum</i>)	Stamen	2.6	0.44	0.5	0.1						
37		Petals	2.4	0.35	0.5	0.1						
38		Bracts	1.5	0.65	1.4	0.1	0.24					
39		Fruit						11		Trace		
40		Seed	1.1-1.2	0.22-0.31	0.06-0.1	0.1	0.02-0.03					
41		Shoot, veg.	2.8-2.9	0.24-0.36	0.4-0.5	0.1-0.2	0.14-0.17	15-50	4-12	50-270	79-90	18-40
42	Oat	Shoot, fl.	2.0-2.2	0.21-0.48	0.3-0.7	0.1-0.3	0.07-0.57	2-17	3-4	154	5-82	12-25
43	(<i>Avena</i>	Shoot, fr.	0.8-2.2	0.16-0.40	0.2-0.5	0.1-0.4	0.07-0.28		1-9		5-116	12-13
44	<i>sativa</i>)	Roots										19-550
45		Straw	0.6-3.5	0.02-0.36	0.2-0.7	0.1-0.5	0.08-0.51	8	2-54	61-860	4-1656	4-193
46		Seed	0.3-1.1	0.15-0.96	0.02-0.19	0.1-0.4	0.02-0.29	1-19	0.7-51	7-350	14-76	22-40
47		Young lvs.	1.6	0.18	4.3	0.1	0.23					
48		Old lvs.	0.1	0.11	8.2	0.1	0.26	17-386 ²	7-18	38-345	24-46	24-47 ²
49		Twig bark	0.6	0.28	5.2	0.1	0.27					
50	Orange	Twig wood	0.2	0.22	1.3	0.1	0.12					
51	(<i>Citrus</i>	Trunk bark	0.7	0.24	4.4	0.4	0.18					
52	<i>sinensis</i>)	Trunk wood	0.2	0.16	0.7	0.1	0.11					
53		Root bark	0.8	0.24	3.3	0.2	0.20					
54		Root wood	0.2	0.16	0.7	0.1	0.08					
55		Small roots	0.16-1.25	0.25	0.4-0.5	0.2-0.8	0.14	95 ²				240 ²
56		Leaves	1.6-1.9	0.24-0.35	6.3-7.6	1.1-3.2	0.43-0.66	43-728				
57		Petioles	0.8	0.12	1.5	0.6	0.09					
58		Upper stems	2.5	0.13	0.7	0.2	0.09					
59		Lower stems	1.4	0.09	0.5	0.2	0.17					
60	Sunflower	Roots	1.4-3.8	0.10-0.34	0.4-2.2	0.1-1.3	0.34	30-77				
61	(<i>Helianthus</i>	Flowers	1.6	0.41	0.8	0.3	0.08					
62	<i>annuus</i>)	Fruits	1.0-3.2	0.32-0.50	0.3-1.0	0.2-0.3	0.19			34	23	19
63		Fruit coats	0.9	0.07	0.4	0.2	0.05					
64		Head minus fr.	9.4	0.41	2.5	1.3	0.46					
65		Seed	1.0	1.01	0.1-0.2	0.4	0.02					
66		Leaves, veg.	4.9	1.06	4.2	0.8		21-150 ²	12-21 ²	106-840 ²	53-4930 ²	17-30 ⁵
67		Leaves, early fl.	5.8	1.07	4.1	0.8						
68		Leaves, fl.	3.3	0.63	3.4	0.5						
69		Leaves, early fr.	2.5	0.59	3.1	0.5						
70		Leaves, mid-fr.	1.8	0.46	4.2	0.6						
71		Stems, veg.	10.7	0.63	3.2	0.8		21-26 ²	6-13	110-230	14-45 ²	
72	Tomato,	Stems, early fl.	10.2	0.78	3.2	0.9						
73	Pan America	Stems, fl.	3.8	0.59	1.6	0.4						
74	(<i>Lycopersicon</i>) ⁶	Stems, early fr.	2.2	0.55	1.7	0.3						
75		Stems, mid-fr.	1.3	0.43	1.8	0.4						
76		Roots, veg.	5.1	0.71	1.4	0.6						
77		Roots, early fl.	5.5	0.85	1.5	0.7						
78		Roots, fl.	2.1	0.98	1.7	0.5						
79		Roots, early fr.	2.2	1.08	1.9	0.7						
80		Roots, mid-fr.	1.4	1.18	2.8	0.5						
81		Fruits	4.0	0.74	0.4	0.1		13-36	4-34	32-800	2-410	2-67

/1/ Veg. = plants in vegetative condition; fl. = plants flowering; fr. = plants fruiting. Shoots are stems with terminal buds and leaves. /2/ Value from unspecified condition of growth. /3/ Value for stover (mature cured stalk, without ears). /4/ Values for *Hirsutum* sp. /5/ Value for leaflets. /6/ *L. esculentum* x *L. pimpinellifolium*.

65. SEEDS: CHEMICAL COMPOSITION

Values, except as otherwise indicated, are g or mg per 100g seeds.

Species	Gross Composition					Amino Acids											Fatty Acids					Vitamins			
	Water	Protein	Fat	Carbohydrate	Ash	Arginine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Threonine	Tryptophan	Tyrosine	Valine	Palmitic	Stearic	Oleic	Linoleic	Linolenic	Niacin	Pantothenic Acid	Riboflavin	Thiamine
	g/100g																g/100g fat					mg/100g			
1 Barley (<i>Hordeum vulgare</i>)	11.1	8.2	1.0	78.8	0.9	0.61	0.26	0.51	0.84	0.42	0.19	0.62	0.48	0.19		0.61	9	3	33	54		3.1	0.66	0.08	0.12
2 Bean, lima (<i>Phaseolus vulgaris</i> mac.)	12.6	20.7	1.3	61.6	3.8																	2.0	0.84	0.18	0.48
3 Bean, mung (<i>P. aureus</i>)	9.8	23.3	1.0	62.0	3.9	0.30	0.21	0.12	3.2	0.74	0.25	1.2	0.60	0.17	0.66	1.9	28	8	18	40	3	2.0	0.21	0.68	
4 Chick-pea (<i>Cicer arietinum</i>)	10.6	20.8	4.7	60.9	3.0																	1.6	0.18	0.49	
5 Corn (<i>Zea mays</i>)	13.0	8.8	4.0	73.0	1.2	0.45	0.24	0.36	1.1	0.29	0.21	0.46	0.34	0.08		0.50	10.2	3.0	50	34		2.8	0.64	0.10	0.49
6 Cotton (<i>Gossypium hirsutum</i>) ²	7.3	23.1	22.9	43.2	3.5	3.0	1.1	1.8	2.2	1.5	0.5	2.2	1.1	0.4	0.6	1.8	←27→		19	54		4.4	0.31		
7 Cowpea (<i>Vigna sinensis</i>)	10.6	22.9	1.4	61.6	3.5																	2.2	0.16	0.92	
8 Flax (<i>Linum usitatissimum</i>) ²	6.2	24.0	35.9	30.3	3.6	3.6	0.65	1.8	2.3	1.4	0.35	2.2	1.3	0.63		2.2									
9 Gingko (<i>Ginkgo biloba</i>)	7.3	7.2	1.6	41.2	1.7																				
10 Hemp (<i>Cannabis sativa</i>)	7.0	28	37														←10.1→		16	46	28				
11 Lentil (<i>Lens culinaris</i>)	11.2	25.0	1.0	59.5	3.3																	2.2		0.24	0.56
12 Lotus (<i>Nelumbium nelumbo</i>)	9.6	16.5	2.3	63.9	3.6																				
13 Oat (<i>Avena sativa</i>)	9.8	12.0	4.6	69.6	4.0	0.99	0.23	0.80	0.87	0.51	0.23	0.72	0.54	0.20	0.50	0.99	10		59	31		1.0	0.63	0.13	0.92
14 Pea (<i>Pisum sativum</i>)	11.6	23.8	1.4	60.2	3.0	2.6	0.4	1.2	1.9	1.5	0.1	1.4	1.2	0.2		1.2						3.1	1.01	0.28	0.77
15 Peanut (<i>Arachis hypogaea</i>) ²	4.0	26.2	42.8	24.3	2.7	6.9	1.3	2.6	4.1	1.9	0.6	3.1	1.6	0.8		2.8	6.3	4.9	61	21.8		15.6	3.50	1.3	1.09
16 Pigeon-pea (<i>Cajanus cajan</i>)	13.1	21.9	1.6	59.9	3.5																	2.0	0.18	0.47	
17 Popcorn (<i>Zea mays praecox</i>)	9.8	11.9	4.7	72.1	1.5																	2.1	0.11	0.39	
18 Pumpkin (<i>Cucurbita pepo</i>)	2.4	22.9	31.9	13.2	3.6																	1.5	0.10	0.18	
19 Rape (<i>Brassica napus</i>)	9.5	20.4	43.6	22.3	4.2												1		32	15					
20 Rice (<i>Oryza sativa</i>)	12.0	7.5	1.7	77.7	1.1	0.54	0.14	0.28	0.51	0.28	0.14	0.31	0.22	0.10		0.40	13.2	1.9	44	39		4.6	1.01	0.05	0.32
21 Rye (<i>Secale cereale</i>)	11.0	12.1	1.7	73.4	1.8	0.59	0.25	0.44	0.67	0.45	0.18	0.47	0.37	0.14		0.56	←21→		18	61		1.6	0.92	0.22	0.43
22 Safflower (<i>Carthamus tinctorius</i>)	6.0	12.7	30.8		3.0												←5.8→		16	78					
23 Sesame (<i>Sesamum indicum</i>)	5.8	19.3	51.1	18.1	5.7																	4.5	0.22	0.93	
24 Sorghum (<i>Sorghum vulgare</i>)	10.0	11.2	3.5	73.8	1.5												8.5					4.5	1.04	0.13	
25 Soybean (<i>Glycine soja</i>) ²	7.5	34.9	18.1	34.8	4.7	4.1	1.3	2.6	4.3	3.1	0.5	3.1	2.3	0.7		2.7	←15→		27	52	6	2.3	1.56	0.31	1.07
26 Sunflower (<i>Helianthus annuus</i>) ²	5.0	18.5	27.8		3.3	5.46	1.43	2.78	3.71	1.45	1.61	2.39	1.64	1.14		2.70	←1.3→		30	60					
27 Wheat (<i>Triticum esculentum</i>)	12.5	12.3	1.8	71.7	1.7	0.63	0.31	0.58	0.91	0.35	0.22	0.70	0.38	0.19		0.64	13.8	1.0	30	49	6	4.3	1.39	0.12	0.52

/1/ Component fatty acids are expressed as per cent by weight of the total fatty acids of the seed. /2/ Values for amino acids are applicable to meal or flour.

66. POLLEN: PROXIMATE CHEMICAL COMPOSITION

Data applicable to bee-collected pollen except for species indicated by an asterisk (*). Bees add reducing sugars, such as honey or nectar, when collecting pollen. Values are g per 100 g pollen.

Species								Species									
Water	Protein	Fat	Starch	Reducing Sugar	Non-reducing Sugar	Ash		Water	Protein	Fat	Starch	Reducing Sugar	Non-reducing Sugar	Ash			
g/100g pollen								g/100g pollen									
1	Almond (<i>Prunus amygdalus</i>)	9.8	28.7	3.2	0.7	24.4	3.1	2.6	14	Mustard, black (<i>Brassica nigra</i>)	13.2	21.7	8.6	2.7	22.0	1.2	2.5
2	Asparagus (<i>Asparagus officinalis</i>)	10.7	25.6	4.1	1.4	20.0	4.6	4.4	15	Mustard, common (<i>B. campestris</i>)	9.9	25.3	9.6	1.1	21.7	1.8	2.8
3	Bermuda grass (<i>Cynodon dactylon</i>)	13.3	20.4	2.4	0.4	25.5	3.4	3.1	16	Oak (<i>Quercus kelloggii</i>)	11.5	19.1	6.6	2.8	32.5	2.0	2.0
4	Birch brush (<i>Ceanothus integerrimus</i>)	10.1	26.1	0.9	0	19.6	4.8	3.1	17	Olive (<i>Olea europae</i>)	10.1	16.7	4.7	1.1	28.3	5.8	1.9
5	Buckthorn (<i>C. crassifolius</i>)	8.1	29.9	1.2	2.0	23.5	3.7	3.1	18	Peach (<i>Prunus persica</i>)	8.5	26.5	2.7	1.6	21.8	9.0	2.8
6	Cattail (<i>Typha latifolia</i>)*	6.4	18.8	1.3	13.0	0.04	18.9	3.8	19	Pine, digger (<i>Pinus sabiniana</i>)*	14.1	11.4	2.7	2.2	7.5	3.5	2.6
7	Chamaebatia (<i>Chamaebatia foliolosa</i>)	15.7	23.4	4.2	2.8	27.7	0	2.6	20	Pine, lodgepole (<i>P. contorta</i>)	7.0	7.0	2.0	3.7	41.2	3.4	1.3
8	Clover (<i>Trifolium</i> sp)	13.4	20.7	3.2	7.8	20.0	2.4	5.5	21	Pine, Monterey (<i>P. radiata</i>)*	11.2	13.4	1.8	2.4	0.05	11.4	2.4
9	Clover, Ladino (<i>T. repens</i>)	11.6	23.7	3.4	1.3	21.4	4.2	3.1	22	Red-maids (<i>Calandrinia ciliata</i>)	9.1	16.8	5.7	7.1	29.1	2.7	2.7
10	Corn (<i>Zea mays</i>)*	5.5	20.3	3.7	22.4	6.9	7.3	2.6	23	Thistle, milk (<i>Silbum marianum</i>)	15.4	19.9	7.6	1.2	26.4	0.2	1.9
11	Dandelion (<i>Taraxacum vulgare</i>)	10.9	11.1	14.4	2.0	32.4	0.6	0.9	24	Thistle (<i>Centaurea solstitialis</i>)	16.2	21.2	6.6	1.2	21.6	2.1	1.8
12	Date (<i>Phoenix dactylifera</i>)	17.1	35.5	3.1	0	1.1	0.1	6.4	25	Walnut (<i>Juglans hindsii</i>)	3.9	23.2	17.6				3.1
13	Eucalyptus (<i>Eucalyptus globulus</i>)*	9.1	26.2	1.4	2.0	21.5	6.5	2.7	26	Willow, black (<i>Salix nigra</i>)	12.3	22.2	4.2	1.4	30.2	0.6	2.6

67. LIGNIFIED CELL WALLS: CHEMICAL COMPOSITION

Values are grams per 100 grams, dry-weight tissue.

Constituent		Beech (Fagus) ¹		Fir (Abies) ²		Spruce (Picea) ³		Pine (Pinus sylvestris)				Poplar ⁴		Rye ⁵	Wheat ⁶
		Sapwood	Heartwood	Sapwood	Heartwood	Sapwood	Heartwood	Sapwood	Heartwood	Wood Near Branches	Branch Wood	17 yr old	43 yr old		
1	Cellulose	49 ⁷				49 ⁷		49	50	51	47	47	44	52	48
2	Mannan					9.1 ⁷		12	9.8	7.7	7				
3	Galactan					0.3 ⁷		0.3	0.5	1.1	1.6				
4	Hexosans											16.1	16.7		
5	Pentosans	27 ⁷				6.7 ⁷		10	11.1	11.6	13.4	15.9	17.1	30	27
6	Polyuronides					2.5 ⁷									
7	Lignin	23 ⁷				28 ⁷		29	29	29	31	19.3	24.3	15.7	16.2
8	Liposoluble extract					1.8 ⁷		3.5	5.9	12.1	29	2	2.4	3	4.1
9	Water	97	65	189	45	170	34								
10	Protein	0.13	0.12	0.098	0.091	0.06	0.06								
11	Fat	0.32	0.27	0.07	0.35	0.53	1.25								
12	Starch	0.08	0.07												
13	Hexosan	↑	↑	11.76	8.42	9.21	9.23								
14	Xylan	20.8	20.0	12.54	10.44	13.48	11.40								
15	Methylpentosan	↓	↓	2.02	2.60	1.34	1.52								
16	Lignin	22.9	22.9	28.7	29.6	30.3	30.2								
17	Cellulose	49.3	49.3	40.1	41.8	39.1	40.3								
18	Water-soluble sugars	2.4	1.4	1.66	2.14	1.86	1.61								
19	Resin and wax	0.06	0.14	0.40	1.76	0.63	2.18								
20	Humin			5.79	5.51	5.76	5.80								
21	Ash	0.39	0.33	0.25	0.42	0.24	0.30					0.8	0.7	5.5	6.5
22	K ₂ O	0.12	0.09	0.05	0.16	0.04	0.04								
23	Na ₂ O	0.002	0.003												
24	CaO	0.12	0.12	0.11	0.09	0.12	0.13								
25	MgO	0.04	0.03	0.03	0.04	0.05	0.04								
26	MnO	0.004	0.003												
27	Fe ₂ O ₃	0.02	0.03												
28	SiO ₂	0.02	0.03												
29	P ₂ O ₅	0.02	0.02	0.02											
30	SO ₃	0.03	0.03			0.03	0.03								
31	Cl	0.007	0.005	0.004	0.005	0.001	0.002								

/1/ Fagus sylvatica. /2/ Abies alba. /3/ Picea abies. /4/ Populus canadensis. /5/ Secale cereale. /6/ Triticum esculentum. /7/ Type of wood unspecified.

68. CORN COLEOPTILE: CHEMICAL COMPOSITION

Constituent	9 mm ¹		32 mm ¹		55 mm ¹		Constituent	9 mm ¹		32 mm ¹		55 mm ¹	
	mg ²	g/100g ³	mg ²	g/100g ³	mg ²	g/100g ³		mg ²	g/100g ³	mg ²	g/100g ³	mg ²	g/100g ³
1 Cell wall							4 Cell content						
2 Cellulose	0.19	8.3	0.93	13.2	1.62	13.0	4 Water solubles	1.02	44	2.65	40	5.70	46
3 Hemicelluloses	0.23	9.0	0.97	14.5	1.37	11.0	5 Protein	0.51	22.2	1.02	15.2	1.63	13.1
3 Pectin	0.05	2.2	0.27	4.0	0.58	4.7	6 Ash	0.16	6.9	0.30	4.4	0.44	3.6

/1/ Refers to length of corn coleoptile. /2/ mg per coleoptile. /3/ Grams per 100 grams, dry-weight tissue.

69. NECTAR: SUGAR CONTENT

Unless otherwise specified, values are grams of indicated sugar per 100 grams or milliliters nectar.

Unless otherwise specified, values are grams of indicated sugar per 100 grams or milliliters of nectar.																		
Species		Total Sugar		Species		Total Sugar	Fructose	Glucose										
		mg/1l/24 hr	g/100g ²			g/100ml	g/100ml	g/100ml										
1	Alfalfa (<i>Medicago sativa</i>)	0.1	33	23	Basswood (<i>Tilia vulgaris</i>)	21-42	5.4-10	5.3-9.8										
2	Apple (<i>Pyrus malus</i>)	0.8	75	24	Blackberry (<i>Rubus fruticosus</i>)	15.4-45	5.2-14.2	5.3-13.5										
3	Banana (<i>Musa paradisiaca sapientum</i>)	74	27	25	Borage (<i>Borago officinalis</i>)	22-29	3.8-6.8	4.0-6.9										
4	Cherry, sour (<i>Prunus cerasus</i>)	1.2	15	26	Clover (<i>Trifolium pratense</i>)	8.3-30	2.3-8.0	0.7-2.2										
5	Cherry, sweet (<i>P. avium</i>)	0.5	21	27	Clover (<i>T. repens</i>)	25-39	9.6-14.2	7.7-12.2										
6	Cucumber (<i>Cucumis sativus</i>)	1.0	30	28	Fireweed (<i>Epilobium angustifolium</i>)	18.4-41	7.9-16.3	5.5-11.3										
7	Horsechestnut (<i>Aesculus hippocastanum</i>)	1.1 ²	69	29	Ivy (<i>Hedera helix</i>)	10-11.5	2.5-2.6	7.6-8.7										
8	Hound's-tongue (<i>Cynoglossum amabile</i>)	0.3	36	30	Lavender (<i>Lavandula spica</i>)	24-32	2.8-4.4	2.0-3.2										
9	Jasmine (<i>Jasminum primulinum</i>)	0.3	33	31	Loganberry (<i>Rubus loganobaccus</i>)	17-51	8.3-26	8.3-25										
10	Locust (<i>Robinia pseudoacacia</i>)	1.0	55	32	Mint (<i>Pycnanthemum pilosum</i>)	14-26	4.6-9.4	0.2-0.6										
11	Milkweed (<i>Asclepias cornutii</i>)	3.1	58	33	Mustard (<i>Brassica alba</i>)	9.3-17.6	4.3-8.3	5.2-9.5										
12	Morning glory (<i>Ipomoea purpurea</i>)	8.0	41	<table><tr><th>Species</th><th>Total Sugar</th><th>Sucrose</th><th>Fructose</th><th>Glucose</th></tr><tr><th></th><th>g/100g</th><th>g/100g</th><th>g/100g</th><th>g/100g</th></tr></table>					Species	Total Sugar	Sucrose	Fructose	Glucose		g/100g	g/100g	g/100g	g/100g
Species	Total Sugar	Sucrose	Fructose						Glucose									
	g/100g	g/100g	g/100g	g/100g														
13	Nasturtium (<i>Tropaeolum majus</i>)	1.7	46	34	Cotton, acala (<i>Gossypium</i> sp)	28	0.71	14.27	10.36									
14	Nettle (<i>Lamium album</i>)	0.8 ²	42	35	Cotton, pima (<i>G. barbadense</i>)	20	0.35	10.36	9.25									
15	Pear (<i>Pyrus communis</i>)	0.3	16	36	Eucalyptus (<i>Eucalyptus globulus</i>)	16.5	5.78	5.47	5.23									
16	Pumpkin (<i>Cucurbita pepo</i>)	28	28	37	Prune, French (<i>Prunus domestica</i>)	20	1.83	← 18.20 →										
17	Rape (<i>Brassica napus</i>)	0.5	47	38	Prune, Italian (<i>P. domestica</i>)	9.9	0.76	← 9.10 →										
18	Raspberry (<i>Rubus idaeus</i>)	7.6	46	39	Poinsettia (<i>Euphorbia pulcherrima</i>)	48	9.69	17.48	21.01									
19	Snapdragon (<i>Antirrhinum majus</i>)	1.5	45	40	Orange, navel (<i>Citrus sinensis</i>)	26	12.87	7.46	5.42									
20	Storax (<i>Styrax officinalis</i>)	1.1	79	41	Orange, Valencia (<i>C. sinensis</i>)	23.4	12.38	6.08	5.06									
21	Sunflower (<i>Helianthus annuus</i>)	0.3	38	42	Wax-plant (<i>Hoya carnosa</i>)	41	29	← 11.9 →										
22	Sweetclover (<i>Melilotus alba</i>)	0.04	36															

/1/ mg of nectar sugar produced by each flower of the plant specified per 24 hr period. /2/ Value from small number of determinations.

70. PLANT MICROORGANISMS AND RELATED MATERIALS: CHEMICAL COMPOSITION

Values, except those for "Water, Free," are grams per 100 grams dry weight of organism, whole virus complex, or related material. Those for "Water, Free," are grams per 100 grams wet weight, except where otherwise indicated.

Organism or Related Material	Protein	Carbo- hydrate ¹	Lipid, Total	Nucleic Acid		Water, Free	Ash	Elements				
				DNA ²	RNA ³			C	H	N	P	S
Fungi												
1 Alternaria spp								46.0-51.0		4.0		
2 Aspergillus clavatus	22-35	57.6	7.6-16.6					48.8		3.6-5.6		
3 A. nidulans	13-26	54.5	16.8-19.9					49.4		2.1-4.1		
4 A. niger	28.1	69.3	0.3-26			1.5-7.5		41.0-49.4		4.7-7.6	0.1-0.3	0.08-0.13
5 A. oryzae	34-38	61.3	1.8-5.6			8.1		42.1-45.8		5.4-6.1	1.72	0.04
6 A. sydowi	21-35	68.1	5.0-12.0					39.8-52.2		3.3-5.7		
7 Cephalothecium roseum								52.5				
8 Cladosporium spp								52.5-53.5		2.6		
9 Dematium pullulans								44.1		2.8-4.7		
10 Fusarium javanicum								55.5				
11 Gliocladium spp								53.1		2.4		
12 Helminthosporium gramineum								51.3		3.2-3.7		
13 Mucor stolonifer			7.0			6.9				8.2		
14 Penicillium chrysogenum	15-44	54.0	2.3-7.1					45.4-48.2		2.4-7.0		
15 P. cyaneo-fulvum	22-36	60.5	3.2-8.2									
16 Rhizopus nigricans						6.1-12.2				5.8		
17 Rhodotorula gracilis			31.2-49									
18 Saccharomyces cerevisiae	61.3	25.4 ⁴	4.8			8.5				8.4		
19 Sordaria spp								49.8				
20 Sporotrichum carneolum								51.1				
21 Trichoderma lignorum								49.4		2.6-10.3		
22 Torulopsis lipofera			28.1							5.4	5.2	
23 T. utilis			6.4							7.3-9.2		
24 Ustilago avenae								52.0				
25 Yeast		790-830 ⁵	7			61-67	8.7			7.5		
26 Yeast cell wall	13	+	8.5			11.2	3.2			2.1	0.3	
Bacteria												
27 Agrobacterium tumefaciens		1.5	7-8.1			5.0-8.2 ⁶	6.8-27.8			5.3-10.3	2.0-4.3	0-0.3
28 Azotobacter chroococcum						85	4.2	22.4		2.9		
29 Bacillus anthracis						80	7.8			9.2		
30 B. anthracis, spores						85	1.2	52.1	6.8	12.4-16.2		
31 B. mycoides	52.4		0.4			88	5.6			10.3-11.3		
32 B. subtilis	10.1% ⁷		4.4			08	10.8			10.1	3.1	
33 B. subtilis, spores	63.7			1.5	4.4	69 ⁸				11.2	1.8	
34 Brucella abortus	13.3% ⁷	1.1-1.5 ⁹	5-6			4-5 ⁶	4.8-5.1			13.2-13.4	1.2	0.5
35 Br. melitensis	12.8% ⁷	1.8-2.7 ⁹				3.5-5.1 ⁶	4.5-5.3			12.7-13	1.3	0.4
36 Br. suis	13.8% ⁷	2.6-3.4 ⁹				1.1-2.2 ⁶	4.3-5.1			13.7-14	1.4	0.6
37 Corynebact. diphtheriae	9.8% ⁷		4.9	1.7	4.8	84		48.9	8.6	9.8-11.2	0.6	1.4
38 Diplococcus pneumoniae ¹⁰	10.4% ⁷						5.8 ¹¹	50 ¹¹		9.4		
39 Escherichia coli	72.4	4.0	4.0	5.2	19.1	73	8.6			11.9-13.2	2.7	0.1
40 Klebsiella pneumoniae	8.9% ⁷	36.1				86	3.0-7.2	49		8.9		
41 Malleomyces mallei	12.6% ⁷		39.3			76	5.2	41.8	5.9	12.6-14.0	1.1	1.0
42 Micrococcus pyogenes ¹²	54.9		2.8				13.9			13.2	1.8	0.4
43 Mycobact. tuberculosis	53.6		39.0			85.9	9.6	47.4-63	7-9.2	7.3-9.4	0.6-2.7	0.2-1.4
44 Neisseria gonorrhoeae		5.1-5.3	10-10.3				7.2-8.9			12.4-13.3		7.2-8.9
45 Proteus vulgaris	47.0	14.2	11.5			80	10.9			8.8		
46 Pseudomonas aeruginosa				4.9	4.4	75	9.0			10.3		
47 Salmonella typhimurium	9.6% ⁷		4.9			78				9.6		
48 S. typhosa	9.9% ⁷					79	5.7			9.9		
49 Serratia marcescens						78	8.9-13.9			10.6		
50 Shigella dysenteriae	74.0 ¹³		5.4 ¹³			78	8.3			8.9		
51 Streptococcus pyogenes ¹⁴										13.2-13.7	2.3	
52 Vibrio comma	73.1			2.1	1.6	73	1.3-3.7	50		9.8-12.3		
Viruses, Rickettsiae and Related Materials												
53 Equine encephalomyelitis ¹⁵	49	4.0	54	0	4.4		2.8	62.2	9.2	7.7	2.2	
54 Influenza A, PR 8	65	4-8 ⁴	44	0	0.9	52.0	3.3	53.2-55.1	7.9	10.0-10.3	0.9-1.1	
55 Influenza B, Lee	64	13.1(?)	33	0	0.9	34.5		52.7		9.6-10.4	0.7-0.94	
56 Influenza, swine	68	10.0	24	+	?	43.3		51.4		9.0	0.87	
57 Japanese B encephalitis							4.8	54.4	7.5	11.9	1.5	
58 Newcastle disease ¹⁶	67	7.1	27					51.8		9.9	0.85	
59 Rabbit papilloma, Shope	90	6.5	1.5 ¹⁷	8.7		58.0	2.5	49.6	7.2	14.5-15.0	0.94	2.2
60 Rous sarcoma							2.0-5.8			15.3		
61 Vaccinia, element. bodies	89	2.8	5.7	5.6	0	5.6 ⁶	0.72	33.7		15.3	0.57	
62 Alfalfa mosaic	85	9.0			15		3.0	53.8	6.7	16.2	1.4	0.65
63 Cucumber, 3, 4	94	2.3			6		2.3	50.0	7.0	15.4	0.54	0
64 Potato mosaic, latent	92				6			47.8	7.4±18	14.6-16.1	0.5-0.7	1.1
65 Ribgrass mosaic	94	2.3			6		2.3	50.3	7.0	15.7	0.6	0.64
66 Southern bean mosaic	79				21		5.7	45.6	6.5	17.0	1.9	1.3
67 Tobacco mosaic	94	2.5		0	6		1.5	51.0	7.6	16.6	0.56	0.2
68 Tobacco necrosis	82	6.5			18		5.8-7.0	45.0	6.5	16.3	1.6	1.6
69 Tobacco ringspot	60	18.0		0	40			50.5	7.6	14.6	3.6	0.39
70 Tomato mosaic, aucuba		2.5			6		1.5	50.0	7.0	16.7	0.52	0.2
71 Tomato bushy stunt	83	6.0		0	17		3.0	47.5	7.7±19	15.8-16.4	1.3-1.5	0.4-0.8
72 Tomato enation		2.5			6		1.0	50.0	7.0	16.7	0.54	0.3
73 Turnip mosaic, yellow	65					35				14.4-15.3	3.4	
74 Bacteriophage, staph.		1.5					13	40.6-41.8	5.3	14.1-14.6	4.6-5.0	
75 Bacteriophage, T ₂	51	13.6	2.6(?)	50	0			42.0		13.5	4.8	
76 Rickettsia prowazeki	35	4.1	47	1.5±21			3.0			12.2	0.93	
77 Chick embryo tissue ²²	41	7.0	35	0	10.6							

/1/ By difference (includes ash varying from 2.5-8.5%), unless otherwise indicated. /2/ Desoxyribonucleic acid. /3/ Ribonucleic acid. /4/ Actual analysis. /5/ As µg glucose. /6/ Loss in water. /7/ Percent nitrogen. /8/ Bound water. /9/ Crude C polysaccharide. /10/ Type I. /11/ Type not specified. /12/ Var. aureus. /13/ Paratyphoid, Flexner. /14/ Mucoid. /15/ Eastern. /16/ California. /17/ Fatty acid. /18/ Range 7.3-7.6. /19/ Range 7.2-8.2. /20/ Range 33.4-40.3. /21/ Range 0.5-2.5. /22/ Normal component.

71. PROTEINS, FUNGI, BACTERIA, AND

Values, unless otherwise indicated, are: for protein, grams per 100 grams of protein on a moisture-free, ash-free basis; for fungi and bacteria,

Substance		Alanine	Arginine	Aspartic Acid	Cystine ¹	Glutamic Acid	Glycine	Histidine	Isoleucine	Leucine
Animal Proteins										
1	Actin	6.3	6.6	10.9	0.9	14.8	5.2	2.9	7.5	8.2
2	Albumin, egg	7.6	6.0	9.3	2.8	16.5	3.6	2.9	7.0	9.9
3	Albumin, serum, human		6.2	10.4	5.6	17.4	1.6	3.5	1.7	11.0
4	Casein, α-, cow	3.8	4.3	8.4	0.4	22.5	2.3	2.9	6.4	7.9
5	Casein, human	2.0	3.4	4.7	0.6	20.9		2.0	6.3	12.2
6	Fibrin, beef	4.0	7.7	11.9	1.9	13.8	5.2	2.1	5.7	6.7
7	Fibrinogen, human	3.7	7.8	13.1	2.3	14.6	5.6	2.6	4.8	7.1
8	Fibroin, silk	25.8	1.1	2.6	0.0	2.2	43.6	0.4	1.2	0.9
9	Gelatin	10.0	8.0	7.5	0.1	10.8	26.0	0.8	1.3	2.9
10	Globulin, α-, serum ⁴		7.7	9.0	1.5	21.6	3.1	2.8	1.7	14.2
11	Globulin, β-, serum ⁴		6.8	9.8	3.4	14.5	5.6	2.8	5.0	8.2
12	Globulin, γ-, serum ⁴		4.8	8.8	2.4	11.8	4.2	2.5	2.7	9.3
13	Hemoglobin, horse	9.8	3.7	10.6	0.5	8.2	5.6	7.8	1.6	16.6
14	Hemoglobin, human	10.2	3.3	11.0		7.2	4.8	8.4	0.2	15.1
15	Lactoglobulin, γ-	7.1	2.8	11.6	3.5	20.0	1.5	1.7	8.0	15.8
16	Myosin, rabbit	6.9	7.1	11.4	1.0	22.8	2.9	2.3	5.5	10.3
17	Wool	4.0	10.6	7.4	13.6	14.0	6.8	1.1	4.3	8.6
Enzymes										
18	Pepsin		1.0	16.0	2.1	11.9	6.4	0.8	10.8	10.4
19	Phosphorylase	4.8	11.6	10.4	0.4	13.6	3.9	3.3	6.5	10.5
20	Ribonuclease		5.2	14.2	6.5	13.0	1.3	4.2	3.1	0
Hormones										
21	Growth hormone, ox		9.0	10.4	2.3	12.9	3.7	2.6	4.1	12.1
22	Insulin	4.5	3.4	6.8	12.5	18.6	4.3	5.3	2.8	13.2
23	Lactogenic hormone, sheep		8.6	11.6	3.1	14.1	4.0	4.5	7.2	12.5
Plant Proteins										
24	Arachin, peanut	4.0	13.5	4.9	1.4	17.0	3.2	2.4	7.7	8.0
25	Edestin	5.5	16.7	12.0	1.2	20.7	5.1	2.6	4.6	7.4
26	Gliadin	2.1	2.7	1.3	2.6	45.7	0.5	1.9	5.4	6.5
27	Globulin, pumpkin seed		16.3					2.2	4.6	8.0
28	Globulin, wheat bran		13.3					1.9	3.8	6.4
29	Gluten, corn		2.1		1.0	24.5	4.3	1.5	5.1	16.0
30	Gluten, wheat	2.8	3.3	9.6	1.9	27.0	7.0	1.9	4.2	7.0
31	Phaseolin, kidney bean		6.0					2.2	6.7	10.5
32	Zein	12.3	2.0	6.6	0.9	26.9	0.4	1.7	7.3	23.7
Fungi ⁵										
33	Aspergillus niger		1.0	+		+		0.9	0.9	1.5
34	A. niger, before sporulation		2.6					1.2	1.4	2.6
35	A. niger, after sporulation		1.4					1.5	0.7	1.3
36	A. niger, spores		1.2					0.5	1.0	1.7
37	A. oryzae		+		+			+		
38	A. sydowi		0.6	0.2		0.1		0.1	0.2	1.4
39	Penicillium notatum		1.4					1.7	1.2	2.1
40	Rhizopus nigricans		1.2					1.0	1.0	1.5
41	Rhodotorula rubra		3.7					2.0	2.1	3.3
42	Saccharomyces cerevisiae		2.4					2.7	2.5	3.8
43	Yeast, baker's ⁶		5	8	1.2	11		7	3	5
44	Yeast, brewer's ⁶		10	7	1.5	12		7	3	5
45	Yeast, commercial		4.3		1.0			2.8	5.9	7.4
Bacteria ⁵										
46	Aerobacter aerogenes ⁷		10.4			5.6		3.4		
47	Agrobacter tumefaciens			2.8		1.6				
48	Azotobacter agilis ⁸		9.5		0.4			0.1		
49	A. vinelandii ⁸		8.3-13.2	7.3	0.4	6.8		0.1-7.9		
50	Bacillus brevis ⁷		9.9			7.3		2.5		
51	B. subtilis ⁷		7.6			5.3		2.5		
52	Corynebacterium diphtheriae ⁸		5.3	3.9		3.0		0.6	1.2	1.0
53	Escherichia coli ⁸		6.6-7.8		-			1.9-6.4	6.3	7.4
54	E. coli, bacteriophage ^{9,10} , host ¹¹	8.4	8.2	9.6		9.6	7.9	3.3	4.6	8.7
55	Lactobacillus arabinosus ⁸		3.3			10.5-12.0		1.7-1.9	5.5	5.9-6.2
56	L. casei ⁸		3.6			9.7		1.9	6.2-6.7	6.8
57	Micrococcus pyogenes, S ¹²		8.9					6.3		
58	M. pyogenes, R ¹³		5.4					5.1		
59	Mycobacterium tuberculosis ⁸		3.8-13.8		1.3-1.7	5.1		0.9-7.2		
60	Neisseria gonorrhoeae		4.3-6.0		0.6					
61	Proteus vulgaris ⁷		7.7			4.9		4.4		
62	Streptococcus fecalis ⁷		5.4			4.4		2.0		
63	Streptomyces griseus		2.9					0.8	1.6	3.8
Viruses ⁵										
64	Influenza A, PR 8	2.5	5.0	7.4		7.7	2.5	1.4	5.2	5.3
65	Papilloma, Shope	3.1	7.0	10.7	6.4 ¹⁴	11.4	3.1	1.8	4.1	7.5
66	Polyhedral, silk worm ⁷	4.7	18.4	8.1	+	3.7	5.8	1.4	7.6 ¹³	4 ¹³
67	Cucumber 4	6.1	9.3	13.1	-	6.5	1.5	-	4.6	9.4
68	Rib-grass	6.4	9.9	12.6	-	15.5	1.3	0.7	5.9	9.0
69	Tobacco mosaic	5.1	9.8	13.5	-	11.3	1.9	-	6.6	9.3
70	Tomato aucuba ¹⁶	5.1	11.1	13.7		11.5	1.9	-	5.7	9.2
71	Bacteriophage, E. coli ^{9,10}	9.4	6.5	12.0		12.0	7.3	<2.6	3.9	6.5

/1/ Values are cystine 1/2, and do not include small quantities of cysteine reported for some proteins. /2/ Total nitrogen accounted for by amino proteins of unknown purity, in contrast with the animal and plant proteins which were mostly highly purified preparations. /6/ Expressed as grams bacterial cell infected with bacterial phage. /12/ Var. aureus, smooth. /13/ Var. aureus, rough. /14/ Cysteine plus cystine. /15/ Isoleucine,

VIRUSES: AMINO ACID COMPOSITION

grams per 100 grams dry weight of organism; for viruses, grams per 100 grams of the whole virus complex.

Lysine	Methionine	Phenyl- alanine	Proline	Serine	Threonine	Tryptophan	Tyrosine	Valine	Nitrogen, Total, %	Nitrogen Recovered ² , %	Hydrolysate, Total ³ , %	
Animal Proteins												
7.6	4.5	4.8	5.1	5.9	7.0	2.0	5.8	4.9	16.7	96	111	1
6.5	5.3	7.2	3.8	8.2	4.0	1.2	4.1	8.8	15.8	97	115	2
12.3	1.3	7.8	5.1	3.7	5.0	0.2	4.7	7.7	16.0			3
8.9	2.5	4.6	7.5	6.3	4.9	1.6	8.1	6.3		102		4
5.5	2.2	5.8	8.9	5.4	4.5	1.5	5.4	5.0		79		5
9.0	2.2	7.6	5.3	15.3	9.9	3.6	5.6	5.6	16.8	101	123	6
9.2	2.5	4.6	5.7	6.9	6.2	3.3	5.4	4.1				7
0.8	0.1	1.6	1.0	13.9	1.3	0.4	10.8	3.6	10.0	89	111	8
4.1	0.9	2.6	16.5	3.4	2.2	0.0	0.4	2.3	17.6	95	123	9
8.9	1.4	4.6	4.7	5.0	4.9	1.9	4.5	5.2				10
6.6	1.7	4.7	7.1	7.1	6.1	2.0	6.0	7.0	15.2			11
8.1	1.1	4.6	8.1	11.4	8.4	2.9	6.8	9.7	16.0			12
8.6	1.0	6.5	8.5	5.8	4.4	1.2	2.9	9.0	16.8	97	112	13
9.6	1.4	7.6	4.4	5.0	5.8	1.5	3.0	10.6	16.9			14
11.3	3.2	4.8	5.0	4.4	5.5	1.9	3.7	5.8	15.5	96	118	15
12.4	3.3	4.5	2.5	4.3	4.9	0.8	3.2	4.9	16.7	98	111	16
3.3	0.7	4.0	8.0	9.8	6.5	1.5	5.5	5.4	16.2	88	115	17
Enzymes												
1.5	1.7	6.4	5.0	12.2	9.6	2.4	8.5	7.1	15.4	86	113	18
7.2	2.7	6.2	4.7	3.4	4.4	2.0	5.9	7.3	16.5			19
10.4	4.5	3.6	3.6	12.0	9.0	0	7.9	7.3		99		20
Hormones												
7.2	2.8	7.9			8.9	0.8	4.3	3.9		88		21
2.4	0.0	8.3	2.5	5.2	2.1	0.0	13.4	7.8	15.7	90	110	22
5.3	3.6	4.1	6.2	6.5	4.8	1.2	4.7	5.9	15.9			23
Plant Proteins												
3.5	0.7	6.4	6.0	5.3	2.7	0.7	5.9	4.5	18.3	72	98	24
3.2	2.4	5.9	4.3	6.3	3.9	1.5	4.3	5.7	18.6	102	113	25
0.8	1.7	6.1	13.4	4.9	2.1	0.6	3.2	2.7	17.7	91	105	26
2.8		7.2			2.6			6.5	16.3			27
4.2	1.0	4.2			3.5	0.9		6.6	13.3			28
1.2	2.5	4.6			4.0	0.3	3.8	5.7	10.9	83	82	29
1.7	1.5	4.1	8.0	4.0	2.5	1.2	1.3	4.1	13.5	70	94	30
7.2	1.1	8.0			4.2	0.5		6.0	16			31
0.0	2.2	6.2	10.5	7.7	2.5	0.1	5.3	3.5	16.0	99	120	32
Fungi⁵												
1.0	0.2	0.8			1.1	0.3	0.3	1.1				33
2.7	0.5	1.5			1.7	0.5		1.8				34
1.2	0.2	0.8			0.9	0.3		0.9				35
1.3	0.2	1.0			1.3	0.3		1.3				36
+						+						37
0.8			0.5	1.8	0.4	0.04	0.4	0.1				38
1.5	0.4	1.2			1.4	0.5		1.5				39
1.6	0.3	0.8			1.0	0.2		1.1				40
3.0	0.5	1.7			1.8	0.4		2.5				41
3.1	0.6	2.1			2.4	0.6		2.8				42
8	0.8	3	3	4	4	-	3	7				43
8	0.8	1	3	3	6	-	2	7				44
7.5	2.7	4.1			5.5	1.3	3.6	5.0				45
Bacteria⁵												
6.8							1.4					46
5.8						0.5	2.1					47
2.5-4.1						0.2	2.5					48
7.9							2.2					49
7.5							1.5					50
4.1			3.8			+	3.0	3.9				51
4.8-10.5						0.6-1.9	1.8	6.1				52
8.3	2.9	4.8	3.0	4.9	5.3	1.3	4.3	5.0				53
5.2-5.9	1.1	2.8			3.8	0.5		5.2-5.4				54
7.7	1.1	3.5			4.7	0.4-0.6		5.8				55
9.9												56
1.3-7.7		13.7	4.0			1.7-2.7	1.3-2.1	16.3				57
6.4				2.4-3.0	2.9-3.3	1.1	2.3					58
7.6							2.1					59
2.2	0.6	1.6			2.4	0.7	0.8					60
							3.5					61
Viruses⁵												
3.6	2.3	3.7	2.6	2.2	3.7	1.1	3.1	3.4				64
7.0	2.1	4.6	5.5	4.0	5.1	1.0	5.8	5.4				65
3.0	1.8	+ ¹⁵	2.3	6.7	6.8	?	2.4	2.4				66
2.4	-	9.8	5.7	9.4	7.0	0.5	3.7	8.9				67
1.5	2.2	5.4	5.5	5.7	8.2	1.4	6.8	6.2				68
1.5	-	8.4	5.8	7.2	9.9	2.1	3.8	9.2				69
1.4	-	8.3	5.8	7.0	10.4	2.1	3.7	8.8				70
8.5	<1.3	4.2	5.0	4.8	7.0		3.7	6.5				71

acids. /3/ A value greater than 100 is the result of water addition during hydrolysis. /4/ Human. /5/ These analyses were made on mixtures of amino acid N/100g of whole yeast. /7/ As % of total N. /8/ As % of protein. /9/ T₄ phage. /10/ As % of total amino acids. /11/ Represents the plus leucine plus phenylalanine. /16/ Strain green aucuba.

72. CHROMOSOME NUMBERS: ANIMALS

Phyla are separated by solid lines; other major systematic groupings are separated by broken lines. Changes in alphabetical sequence of sections between lines indicated transitions from one group to another within a class. s = spermatogonium; o = oogonium; m = somatic cell. Data adapted and revised by S. Makino from his "Atlas of Chromosome Numbers in Animals." Superscripts after species refer to sex types in footnotes.

Species	Chromosome Number (2n)	Species	Chromosome Number (2n)	Species	Chromosome Number (2n)
1 Rhopalura ophiocoma ^e	6m	84 Armadillidium opacum	54 s	167 Xiphidion gladiatum ²	33 s
2 Sycon ciliatum	26 m	85 Ligia exotica	72 s	168 X. maculatum ²	21 s
3 Hydra circumcincta	30 m	86 Porcellio scaber	56 s	169 Mantis religiosa ²	27 s
4 H. vulgaris attenuata	32 s, o, m	87 Proasellus meridianus	16 s	170 Creobroter laeviscolis ²	27 s
5 Pelmatohydra obligactis	30 m	88 Trichoniscus elisabethae	16 s (3n, 24s)	171 Iris oratoria ²	25 s
6 Moniezia expansa	12-14(?) m	89 Gammarus chevreuxi	52 s	172 Toxomantis sinensis ²	27 s
7 Fasciola hepatica	12 o, m	90 Cambaroides japonicus	196 s	173 Bostra sp ²	35 s
8 Parorchis acanthus	22 s	91 Macrocheira kamferi	106 s	174 Isagoras sp ²	47 s
9 Schistosoma japonicum	16 s, o	92 Eupagurus ochotensis	254 s	175 Oncotophasma sp ²	41 s
10 Polystomum integerrimum	20 m	93 Telphusa fluviatilis	78 s	176 Pseudophasma menius ²	23 s
11 Aphanostoma diversicolor	20-30	94 Pediculopsis graminum	6 m (parth., 3m)	177 Diestrammena marmorata ²	57 s
12 Stenostomum grandis	20-40	95 Agalena opulenta ³	44 s	178 Tridactylus japonicus ²	13 s
13 Mesostoma ehrenbergii	10 m	96 Aranea dumetorum ³	14 s	179 Labidura riparia ⁵	14 s
14 Microstomum bispiralis	16 s	97 Tetragnatha japonica ³	24 s	180 Isoperla grammica ²	26 s
15 Dalyellia spp	4 s	98 Clubiona japonicola ³	20 s	181 Perla maxima ³	19 s
16 Amphibolus virginiana	4 s	99 Drapetisca socialis ³	24 s	182 Perleides microcephala ⁴	27 s
17 Castrada sp	6 s	100 Heptathela kimurai ³	80 s	183 Zootermopsis angusticollis ²	52 s m
18 Polycystus goetteli	16 s	101 Schizocosa crassipes ³	22 s	184 Cerastiposocus venosus ²	17 s
19 Plagiostomum stellatum	10 s	102 Oxyopes ramosus ²	21 s	185 Lipeurus baculus	12 s m
20 Curtisia foremanii	12 s, o	103 Philodromus roseus ³	28 s	186 Ameletus costalis ⁵	18 s, o
21 Thysanozoon broochi	18 s, m	104 Icius elongatus ³	28 s	187 Ephemerella danica	11 s
22 Micrura caeca	32 m	105 Heteropoda venatoria ⁴	41 s	188 Aeschna coerulea ²	25 s, 26 o
23 Asplanchna intermedia	24 s, o, m	106 Ariamnes cylindrogaster ³	22 s	189 Anax junius ²	27 s, 28 o
24 Dinophilus apatris	20 m	107 Xysticus viaticus ²	23	190 Ictinus rapax ²	23 s
25 Allolobophora chlorotica	32 m	108 Gargrellopsis nogulifera	16 s	191 Diplacodes trivialis ²	25 s
26 Dendrobaena subrubicunda	68 m	109 Buthus martensii	24 s	192 Orthetrum sabina ²	25 s
27 Eisenella tetraedra	72 m	110 Tityus bahiensis	20 s	193 Sympetrum pedemontanum ²	25 s
28 Lanius conchylega	6 m	111 Tachyporus tridentatus	26 s	194 Trithemis pallidinervis ²	25 s
29 Ophryotrocha gracilis	10 s, o, m	112 Porocephalus armillatus	20 o	195 Ceriagrion rubiae ²	27 s
30 Sabellaria spinulosa	8 s, m	113 Macrobiotus lacustris	10 m	196 Lestes sponsa ²	25 s
31 Glossosiphonia complanata	26 s	114 Thereuonema hilgendorfi ⁵	36 s	197 Phyllaphis coweri	5 s, 6 o
32 Protocopsis tessellata	16 m	115 Otocryptops sexspinosus ⁶	15 s, 14 o	198 Aphis oenothera	10 s, m
33 Phascolosoma gouldii	20 m	116 Amurida maritima	8 o	199 A. saliceti ²	5 s, 6 m
34 Sagittia spp	18 s, m	117 Lepisma domestica	34 s	200 Chermes pectinata	20 s m
35 Mactra sp	24 m	118 Acrida turrita ²	23 s	201 Euceraphis betulae	8 s, o, m
36 Compeloma rufum	12 o	119 Attractomorpha ambigua ²	19 s	202 Hyalopterus purni	9 s
37 Pterotrachea mutica	32 m	120 Chorthippus (Stenobothrus) lineatus ²	17 s	203 Macrosiphum pisi ²	7 s, 8 s m
38 Tolutoma magnifica	24	121 Chorthippa viridifasciata ²	23 s	204 Melahaxanthus salicicola	6 s, 7 m
39 Viviparus contectoides	26	122 Chrysocraon japonicus ²	17 s	205 Myzoxylus linderiae ²	11 s, 12 o
40 Limacina retroversa	24 s, m	123 Circotettix verruculatus ²	21 s	206 Phylloxera fallax ³	10 s, o, 7 m
41 Montagua gouldii	32 m	124 Hesperotettix pratensis ²	22 s	207 Tetraneura ulmi ²	13 s, 14 o
42 Lymnaea japonica	36 s	125 Dissosteira sp ²	23 s	208 Aphrophora coctalis ⁵	30 s
43 Arion empiricorum	32 m	126 Gomphoceris rufus ²	17 s	209 Clastoptera obtusa ²	15 s
44 Euhadra awaensis	58 s	127 Locusta migratoria ²	23 s	210 Dactylopius sp	10 s m, 8 s
45 Cepaea hortensis	48 s	128 Mecostethus lineatus ²	23 s	211 Icerya purchasi	4 s, o, m
46 Helicigona arbustorum	48 s	129 Melanoplus dawsonii ²	23 s	212 Gossyparia spuria	28 s, 6 m, 7 m
47 Helix aspersa	54 s	130 Mermiria bivittata ²	22 s, o, m	213 Lecanium hesperidum	14 m
48 H. pomatia univalens	24 s	131 Miramella dairisama ²	21 s	214 Llaveia bouvieri ²	5 s, 6 o
49 Limax cinereus-niger	16 s	132 Oxya intricata ²	23 s	215 Nautococcus schraderae ²	5 s m, 6 s m
50 Inciliaria fruhstorferi	48 s	133 Paratyloptropidia brunneri ²	19 s, 20 s m	216 Pseudococcus acercola	12 s, o
51 Polygra appressa	60-62 s	134 Philocleon anomalus ²	12 s	217 Amphispheca bivittata ²	25 s
52 Stenotrema hirsutum	58 s	135 Podisma mikado ²	21 s	218 Phlepsius irroratus ²	15 s
53 Succinea horticola	34 s	136 Romalea microptera ²	23 s	219 Canpylenchia curvata ²	19 s
54 S. ovalis	40 s	137 Schistocerca gregaria ²	23 s	220 Enchenopa binotata ⁵	20 s, o
55 Echinorhynchus gigas	8 m	138 Stauroderus bicolor ²	17 s	221 Entilia sinuata ²	21 s
56 Ascaris lumbricoides ¹	43-48 s	139 Syrbula sp ²	23 s	222 Vanduzeeia arcuata ²	17 s
57 A. megalocephala bivalens	4 s, o, m	140 Teratodes monticolis ²	23 s	223 Belostoma flumineum ⁵	24 s
58 A. m. univalens	2 s, o, m	141 Traulia ornata ²	23 s	224 Adelphocoris lineolata ²	17 s
59 Spirina parasitifera	14 s	142 Trimerotropis sp ²	23 s	225 Notostira erratica ²	17 s
60 Heterakis sp ²	9 s	143 Zubovskya glacialis ²	21 s	226 Cimex staderi	31 s
61 Rhabditis monohystera	20 o, m	144 Blattella orientalis ²	47 s	227 Alydus calcaratus ²	13 s
62 Ophiostomum mucronatum	12 m	145 Periplaneta australasiae ²	27 s	228 Anasa tristis ²	21 s
63 Strongylus paradoxus ²	11 s	146 Acheta campestris ²	29 s	229 Archimeris alternatus ²	15 s
64 Gordius spp	4 s, o, m	147 Apithes agitator ²	13 s	230 Camptopus lateralis ²	13 s
65 Pedicellina americana	22 s, o, m	148 Endocous cavernicola ²	19 s	231 Metapodius femoratus ²	22 s, o
66 Asterias amurensis	30 s	149 Gryllus assimilis ²	29 s	232 Diactor bilineatus ²	21 s
67 Strongylocentrotus lividus	36 m	150 Lebinthus sp ²	11 s	233 Syromastes marginatus ⁵	22 s, o
68 Toxopneustes variegatus	36 m	151 Liphoplus kanetaki ²	19 s	234 Phthia picta ²	21 s
69 Henricia nipponica	54 s	152 Madasumma hibernica ²	15 s	235 Protenor belfragei ²	13 s, 14 o
70 Artemia salina	42 s (4n, 84s)	153 Oecanthus longicauda ⁵	20 s	236 Callicorixa caledonica ⁵	24 s
71 Daphnia pulex	20 s	154 Scapsipedus sp ²	17 s	237 Cymatia bonndorffi ⁵	26 s
72 Heterocypris incongruens	20 o, m	155 Galloisiana nipponensis ⁵	30 s	238 Corixa punctata ⁵	24 s
73 Calanus finmarchicus	34 s, o	156 Gryllotalpa africana ²	23 s	239 Leptocoris haemotoloma ²	13 s
74 Diaptomus castor	34 m	157 Amblycorypha oblongifolia ²	33 s	240 Dysodius lunatus ⁷	31 s
75 Heterocope weismanni	32 s	158 Conocephalus sp ²	33 s	241 Gerris lateralis ²	21 s
76 Copilia denticornis	16 s	159 Ephippigera vitium ²	29 s	242 Lygaeus turcicus ⁵	14 s, o
77 Cyclops fuscus	14 m	160 Hexacentrus mundus ²	31 s	243 Hygotrechus sp ²	21 s
78 C. gracilis	6 m	161 Isotima japonica ²	27 s	244 Aphanus japonicus ⁸	17 s
79 C. insignis	22 m	162 Kuwayamaea sapporensis ²	27 s	245 Eremocoris erraticus ⁵	20 s
80 C. viridis	12 s, o, m	163 Mecopoda elongata ²	27 s	246 Geocoris japonicus ⁵	20 s, o
81 Hersilia apodiformis	24 s, o, m	164 Odontura maraccana ²	27 s	247 Macrodera micropterum ⁵	18 o
82 Mytilicola intestinalis	22 o, m	165 Saga pedo	68 s m	248 Nysius jacobae ⁵	14 s, o
83 Scalpellum scalpellum	32 s, o	166 Scudderella sp ²	31 s	249 Oncopeltus fasciatus ⁵	16 s, o

/1/ X₁X₅. /2/ X-O. /3/ X₁X₂-O. /4/ 3X-O. /5/ X-Y. /6/ 4X-5Y. /7/ X₁X₂-Y. /8/ 4X-Y.

72. CHROMOSOME NUMBERS: ANIMALS (Concluded)

Phyla are separated by solid lines; other major systematic groupings are separated by broken lines. Changes in alphabetical sequence of sections between lines indicated transitions from one group to another within a class. s = spermatogonium; o = oögonium; m = somatic cell. Data adapted and revised by S. Makino from his "Atlas of Chromosome Numbers in Animals." Superscripts after species refer to sex types in footnotes.

Species	Chromosome Number (2n)	Species	Chromosome Number (2n)	Species	Chromosome Number (2n)
250 Rhyparochromus chiragra ⁵	14 s	333 Coccinella bruchii ⁵	18 s	417 Mollienisia sphepops	46 s
251 Stigonocoris rusticus ⁵	18 o	334 Epilachna pustulosa ⁵	20 s	418 Platypocilus maculatus	48 s
252 Mesovelia furcata ⁸	35 s	335 Harmonia axyridis ⁵	16 s	419 Xiphophorus hellerii	48 s
253 Naucoris cimicoides ²	51 s	336 Synonyma grandis ⁵	20 s, o	420 Oncorhynchus keta	74 s
254 Ranatra linearis ⁹	43 s	337 Acanthoscelides obtectus	20 ♀m	421 Osmerus eperlanus	58 m
255 Notonecta undulata ⁵	26 s	338 Otiorhynchus arcticus	22 s	422 Salmo carpio	96 s
256 Aelia accuminata ⁵	14 s	339 O. gemmatus	33 ♀m (3n)	423 Thymallus thymallus	102 m
257 Banasa calva ⁵	26 s, o	340 O. scaber	44 ♀m (4n)	424 Ichthyophis glutinosus	42 s, o m
258 Coptosoma punctissimum ⁵	12 s	341 Polydrosus mollis	22 o	425 Hynobius nebulosus	56 s
259 Dinidor rufocinctus ¹⁰	21 s, 22 o	342 Hydrous acuminatus ⁵	30 s	426 Amblystoma mexicanum	28 s
260 Dolycoris baccarum ⁵	14 o	343 Psalidoremus inclinator ²	19 s	427 Salamandra salamandra	24 s
261 Eusacoris aeneus ⁵	16 s	344 Meloe sp ⁵	20 s	428 Triturus cristatus	24 s
262 Euschistus fissilis ⁵	14 s, o	345 Anomala rufocuprea ⁵	18 s	429 Cryptobranchus alleghehiensis	62 s
263 Graphosoma rubrolineatum ⁵	14 s	346 Popillia japonica ⁵	18 s	430 Bufo arenarum	22 s
264 Halymorpha picus ⁵	14 s	347 Listrotrophus cingulatus ⁵	26 s	431 B. calamita	22 s
265 Megymenum gracilicorne ⁵	20 s	348 Blaps lusitanica ¹⁵	19 s, 20 o	432 B. viridis	22 s, o
266 Nezara hiliaris ⁵	14 s, o	349 Biaperis boleti ⁵	14 s	433 Alytes obstetricans	36 s
267 Palomena angulosa ⁵	16 s, o	350 Tenebrio molitor ⁵	20 s, o	434 Bombina orientalis	24 s
268 Pentatoma juniperina ⁵	14 s	351 Acroschismus wheeleri	16 s, o, m	435 Hyla arborea	24 s
269 Rhytidolomia sancia ⁵	14 o	352 Apis mellifica	16 s, o	436 Pelobates fuscus	26 s
270 Thyanta calceata ¹⁰	27 s, 28 o	353 Habrobracon pectinophorae	20 s, o	437 Xenopus laevis	36 s
271 Largus cinctus ²	11 s, 12 o	354 Trigonaspis megaptera	10 s	438 Rana japonica	26 s
272 Pyrrhocoris apterus ²	23 s, 24 o	355 Diprion polystomum	6 s, 12 ♀m	439 R. pipiens	26 s
273 Polididus armatus ⁵	12 s	356 Melittobia chalybii	5 ♂m, 10 ♀m	440 R. temporaria	26 s, m
274 Velinus nodipes ¹¹	28 s, 30 o	357 Lasius flava	24 ♀m	441 Rhacophorus schlegelii	26 s
275 Velia currens ²	25 s	358 Aenoplex smithii	13 s, 26 o	442 Alligator mississippiensis	32 s
276 Rhaphidia xanthostigma ⁵	26 s	359 Pteromalus puparum	5 ♂m, 10 ♀m	443 Chelonia japonica ¹³	56 s, 55 o
277 Glyptobasis dentifera ⁵	22 s	360 Thrinax macula	7 s, 14 o	444 Emys orbicularis	50 s
278 Chrysopa aspera ⁵	12 s, o	361 Trichogramma chilonis	5 s, 10 o	445 Calotes versicolor ¹³	34 s, 33 o
279 C. flava ⁵	14 s	362 Polistes fadwage	9 s, 18 o	446 Anguis fragilis	44 s, o
280 C. perla ⁵	12 s, o	363 P. snelleni	13 s, 26 o	447 Chamaelon vulgaris	24 s, o
281 C. vulgaris	12 s, o, ♀m	364 Fucellia marina	12 m	448 Eublepharis variegatus	32 s
282 Semidialis albata	18 o	365 Asilus lecythus ⁵	14 s	449 Gymnodactylus mulliusi	38 s
283 Hemerobius stigma ⁵	14 s	366 Bibio hortulanus ⁵	10 m	450 Heloderma suspectum	38 s
284 Myrmeleon europaeus ⁵	14 s, o	367 Caliphora erythrocephala ⁵	12 s, o, m	451 Anolis carolinensis	34 s
285 Palparens pardus asanai ⁵	26 s	368 Miasor americana	48 s, o, 12 ♀m	452 Sceloporus spinosus	22 s
286 Panorpa japonica ^{2, 12}	46 o	369 Lasiotera asterspinosae	8 ♀m, 6 ♂m, 453	453 Lacerta viridis	38 s
287 Stenopsyche griseipennis ¹³	26 s, 25 ♀m	370 Chironomus spp	8 s, 50 s, o	454 Takydromus tachydromoides	38 s
288 Chaetopteryx villosa	60 s	371 Scatophaga pallida ⁵	12 s, o	455 Lacerta vivipara ¹³	36 s, 35 o
289 Halesus tessellatus	42 s	372 Aedes spp ⁵	6 s, o	456 Scincis officinalis	32 s
290 Limnophorus affinis	12 s	373 Anopheles punctipennis ⁵	6 s, o	457 Ameiva surinamensis	50 s
291 Phragmatobius fuliginosa ¹⁴	56 s, 58 o	374 Culex pipiens ⁵	6 s, o, m	458 Naja naja atra	38 s
292 Abraxas grossulariata	26 s, o	375 Drosophila melanogaster ⁵	8 s, o	459 Ancistrodon acutus	36 s
293 Biston hirtaria	28 s, o	376 D. willistoni ⁵	6 s, m	460 Vipera aspis	42 s
294 Dendrolimus jezoensis	60 s	377 D. melanica ⁵	10 s, o, ♂m	461 Pica pica sericea ¹³	82 s, 81 o
295 Bombyx mori	56 s	378 D. aldrichi ⁵	12 o	462 Cuculus canorus	72 s
296 Lymantria dispar	62 s, o	379 D. virilis ⁵	12 s, o, m	463 Emberiza elegans	84 s
297 L. japonica	62 s, o	380 D. pseudoobscura ⁵	10 s, m	464 Egretta garzetta	76 s
298 Orgyia thyellina	22 s	381 D. ananassae ⁵	8 s, o, m	465 Aix sponsa	80 s
299 Dicranura erminea	56 s	382 D. obscura ⁵	10 s, o, ♂m	466 Anas platyrhynchos ¹³	80 s, 70 o
300 D. vinula fennica	42 m	383 Scatophila unicornis ⁵	13 ♂m, 14 ♀m	467 Cygnus cygnus	80 s
301 D. vinula delavoiei	62 m	384 Melophagus ovinus ⁵	18 s	468 Columba livia domestica ¹³	80 s, 79 o
302 Pygaera curtula	48 m	385 Olfersia bisulcata ⁵	8 s	469 Bambusicola thoracica	78 s
303 P. pigra	46 s, m	386 Dicranomyia trinitata ⁵	6 s	470 Gallus gallus domesticus ¹³	78 s, 77 o
304 Papilio podalirius	54-58 s	387 Liponeura cinerascens ⁵	10 s	471 Meleagris gallopavo ¹³	82 s, 81 o
305 P. rutulus	28 s	388 Musca domestica ⁵	12 s, o	472 Numida meleagris ¹³	76 s, 75 o
306 Pieris brassicae	30 s, o	389 Brachyptera radiata ⁵	12 m	473 Phasianus colchicus karpow ¹³	82 s, 81 o
307 P. napi	50 s	390 Fungivora blanda	8 o, ♀m	474 Syrmaticus soemmerringii	82 s
308 Fumea casta	62 s, 61 o	391 Rhymsia fenestralis ⁵	8 m	475 Didelphys virginiana ⁵	22 s, m
309 Chiro simplex	58 s	392 Camptoneura picta	12 s	476 Myotis myotis ⁵	44 s
310 Callosamia promethea	38 s	393 Piophilha casei	12	477 Erinaceus europaeus ⁵	48 s
311 Philosamia cynthia	26 s, o, ♀m	394 Aphiochaeta sp	6 m	478 Talpa europaea ⁵	34 s
312 P. cynthia walkeri	26 s	395 Physegenia vittata	12 s	479 Lepus cuniculus ⁵	44 s
313 P. cynthia pryeri	28 s	396 Sarcophaga sp ⁵	12 m	480 Cavia cobaya ⁵	64 s
314 Telea polyphemus	60 s	397 Sciara ocellaris	8 m	481 Myocastor coypus ⁵	42 s
315 Deilephila euphorbiae	28 s	398 Simulium sp ⁵	6 m	482 Mesocricetus auratus ⁵	44 s
316 Solenobia alpicolella	60-62	399 Ptecticus trivittatus ⁵	16 s	483 Apodemus agrarius ⁵	48 s
317 S. triquetrella	62 m	400 Eristalis bastardi ⁵	12 s	484 Micromys minutus ⁵	68 s
318 Talaeporia tubulosa	60 ♂m, 59 ♀m	401 Phorocera hamata ⁵	12 ♂m	485 Peromyscus maniculatus ⁵	48 s
319 Tischeria angusticolella	42 s, o	402 Chaetopsis fulvifrons	8 s	486 Mus musculus ⁵	40 s
320 Anthia sexguttata ²	35 s	403 Ctenocephalus canis ⁵	14 ♂m	487 Rattus norvegicus ⁵	42 s
321 Dytiscus circumcinctus ⁵	38 s	404 Leptopsylla musculi ⁵	22 s	488 Cynomys ludovicianus ⁵	52 s
322 Bruchus quadrimaculatus ²	19 s, 20 m	405 Cionia intestinalis	18 m	489 Sciurus vulgaris ⁵	40 s
323 Agrilus anxius ⁵	22 s, o	406 Branchiostoma japonica ⁵	32 s	490 Canis familiaris ⁵	78 s
324 Julodis whitthilli ²	24 s	407 Bdellostoma burgeri	48 (?) s	491 Felis catus ⁵	38 s
325 Sternocera laevigata ²	26 s	408 Protopterus annectens	34 s	492 Phocoenoides dalli ⁵	44 s
326 Pterolophia caudata ⁵	20 s	409 Raja macrorhynchus	24 s	493 Bos taurus ⁵	60 s
327 Agelastica caerulea ⁵	24 s	410 Squalus suckleyi	62 s	494 Ovis aries ⁵	54 s
328 Chrysomela exanthematica ²	23 s	411 Betta splendens	42 s	495 Sus scrofa	40 s
329 Coptocycla clavata ⁵	18 s	412 Misgurnus anguillicaudatus	52 s	496 Equus caballus ⁵	66 s
330 Luperoides praestus ²	32 s, o	413 Acheilognathus lanceolatus	50 s	497 E. asinus ⁵	66 s
331 Melasoma populi ⁵	32 s	414 Carassius auratus	94 s	498 "Mule" ⁵	66 s
332 Calvia 14-guttata ⁵	20 s	415 Cyprinus carpio	104 s	499 Macaca mulatta ⁵	48 s, m
		416 Leibes reticulatus	48 s	500 Homo sapiens	48 s, o

/2/ X-O♂. /5/ X-Y♂. /9/ 5X-O♂. /10/ 2X-Y♂. /11/ 3X-Y♂. /12/ X-X♀. /13/ X-O♀. /14/ Z-2W♀. /15/ 2XX-Y♂.

73. CHROMOSOME NUMBERS: GYMNASPERMS AND ANGIOSPERMS

Extra fragment chromosomes are indicated by "f". Values are diploid chromosome numbers. Data adapted from Darlington, C. D., and Janaki Ammal, E. K., "Chromosome Atlas of Cultivated Plants," G. Allen and Unwin, Ltd., London, 1945.

Species	Number	Species	Number	Species	Number
Gymnospermae		Angiospermae: Monocotyledoneae (concluded)		Angiospermae: Dicotyledoneae (continued)	
1 Cycadaceae		60 Bromeliaceae		107 Betulaceae	
2 Zamia (Zamia floridana)	16	61 Pineapple (Ananas sativus)	50,75,100	108 Alder (Alnus cordata)	42
3 Ginkgoaceae		62 Spanish moss (Tillandsia usneoides)	32	109 Alder (A. glutinosa, A. incana)	28
4 Ginkgo (Ginkgo biloba)	24	63 Commelinaceae		110 Alder (A. japonica)	56
5 Taxaceae		64 Rhoea (Rhoea discolor)	12	111 Alder (A. maritima)	28
6 Yew (Taxus baccata, T. cuspidata)	24	65 Spiderwort (Tradescantia virginiana)	24+0-6f	112 Alder (A. rubra, A. rugosa)	28
7 Yew (T. canadensis)	24+f	66 Wandering-jew (T. fluminensis)	60	113 Alder (A. spaethii)	56
8 Pinaceae		67 Pontederiaceae		114 Alder (A. viridis)	14
9 Arborvitae (Thuja orientalis)	22	68 Water-hyacinth (Eichhornia crassipes)	32	115 Birch (Betula alba)	84
10 Cedar (Cedrus libani)	24	69 Junaceae		116 Birch (B. fontinalis)	28
11 Douglas-fir (Pseudotsuga menziesii)	26	70 Rush (Juncus effusus)	40	117 Birch (B. grossa)	42
12 Fir (Abies balsamea, A. cephalonica)	24	71 Liliaceae		118 Birch (B. lenta)	28
13 Fir (A. concolor, A. normanniana)	24	72 Asparagus (Asparagus officinalis)	20	119 Birch (B. nigra)	28
14 Hemlock (Tsuga canadensis)	24	73 Autumn crocus (Colchicum autumnale)	38	120 Birch (B. papyrifera)	28, 42
15 Hemlock (T. caroliniana)	24	74 Bluebell (Scilla non-scripta)	16	121 Hornbeam (Carpinus spp) ⁷	16
16 Juniper (Juniperus chinensis)	44	75 Garlic (Allium sativum)	16	122 Hornbeam (C. betulus)	8, 64
17 Juniper (J. communis, J. rigida)	22	76 Grape-hyacinth (Muscari racemosum)	54	123 Fagaceae	
18 Larch (Larix decidua)	24	77 Helleboro (Venetrum nigrum)	64	124 Beech (Fagus sylvatica)	24
19 Pine (Pinus spp) ¹	24	78 Hyacinth (Hyacinth orientalis)	16, 19-30	125 Chestnut (Castanea crenata)	24
20 Redcedar (Juniperus virginiana)	22	79 Lily (Lilium spp) ³	24	126 Chestnut (C. dentata, C. mollissima)	24
21 Redcedar (Thuja plicata)	22	80 Lily, day (Hemerocallis flava)	22	127 Oak (Quercus spp) ⁸	24
22 Redwood (Sequoia giganteum)	22	81 Onion (Allium cepa)	16	128 Ulmaceae	
23 Redwood (S. sempervirens)	44	82 Trillium (Trillium grandiflorum)	10	129 Elm (Ulmus spp) ⁹	28
24 Spruce (Picea spp) ²	24	83 Tulip (Tulipa gesneriana)	24, 36	130 Elm (U. americana)	56
25 White-cedar (Thuja occidentalis)	22	84 Amaryllidaceae		131 Moraceae	
Angiospermae: Monocotyledoneae		85 Belladonna (Amaryllis belladonna)	22	132 Fig (Ficus carica)	26
26 Najadaceae		86 Century plant (Agave americana)	60, 120, 180	133 Hemp (Cannabis sativa)	20
27 Eelgrass (Zostera marina, Z. nana)	12	87 Jonquil (Narcissus jonquilla)	14, 28	134 Jack fruit (Artocarpus integra)	56
28 Alismataceae		88 Narcissus (N. poeticus)	14, 21, 28	135 Mulberry (Morus alba, M. indica)	28
29 Alisma (Sagittaria montevidensis)	20	89 Narcissus (N. pseudonarcissus)	14, 15, 20, 22, 28, 30	136 Urticaceae	
30 Plantain (Alisma plantago-aquatica)	10	90 Yucca (Yucca spp)	60	137 Ramie (Boehmeria nivea)	28
31 Hydrocharitaceae		91 Iridaceae		138 Lorantheae	
32 Elodea (Elodea canadensis)	24	92 Crocus (Crocus versicolor)	26	139 Mistletoe (Viscum album)	20
33 Elodea (E. densa)	48	93 Gladiolus (Gladiolus spp)	30	140 Mistletoe (V. articulatum)	24
34 Vallisneria (Vallisneria gigantea)	40	94 Iris (Iris orientalis)	14	141 Polygonaceae	
35 Vallisneria (V. spiralis)	20	95 Iris (I. versicolor)	72, 84, 105	142 Buckwheat (Fagopyrum esculentum)	16
36 Gramineae		96 Musaceae		143 Dock (Rumex aquaticus)	200
37 Barley (Hordeum distichum)	14	97 Banana (Musa paradisiaca sap.)	22, 33	144 Dock (R. crispus)	60
38 Barley (H. jubatum)	28	98 Plantain (M. paradisiaca)	44, 55, 77, 88	145 Rhubarb (Rheum officinale)	22
39 Barley (H. nodosum)	42	99 Zingiberaceae		146 Rhubarb (R. raphaniticum)	44
40 Barley (H. vulgare)	14	100 Ginger (Zingiber officinale)	22	147 Chenopodiaceae	
41 Bluegrass (Poa compressa)	35, 42, 45, 49, 56	101 Cannaceae		148 Beet (Beta vulgaris)	18
42 Bluegrass (P. pratensis)	28-124	102 Cana (Canna discolor, C. flaccida)	18	149 Pigweed (Chenopodium album)	54
43 Corn (Zea mays)	20	103 Orchidaceae		150 Saltbush (Atriplex littoralis)	18
44 Crabgrass (Digitaria sanguinalis)	36	104 Lady's slipper (Cypripedium acaule)	20	151 Spinach (Spinacia oleracea)	12
45 Dallis grass (Paspalum dilatatum)	40	105 Lady's slipper (C. spectabile)	22	152 Portulacaceae	
46 Fescue (Festuca elatior)	14, 28, 42, 70	106 Orchid (Cymbidium giganteum)	40	153 Purslane (Portulaca oleracea)	54
47 Gammagrass (Tripsacum dactyloides)	36, 72	107 Orchid (Dendrobium nobile)	38	154 Caryophyllaceae	
48 Johnson grass (Sorghum halepense)	40	Angiospermae: Dicotyledoneae		155 Carnation (Dianthus caryophyllus)	30, 90
49 Oat (Avena barbata)	28	108 Piperaceae		156 Chickweed (Stellaria media)	40, 44
50 Oat (A. fatua, A. sativa)	42	109 Peperomia (Peperomia sanderi)	24	157 Pink (Dianthus deltoideus)	30
51 Oat (A. strigosa)	14	110 Pepper (Piper nigrum)	128	158 Sweet william (D. barbatus)	30
52 Quackgrass (Agropyron repens)	28, 42	111 Salicaceae		159 Nymphaeaceae	
53 Redtop (Agrostis alba)	28, 42	112 Poplar (Populus spp) ⁴	38	160 Spatterdock (Nuphar advenum)	34
54 Rice (Oryza sativa)	24	113 Willow (Salix alba)	76	161 Waterlily (Nymphaea capensis)	28
55 Rye (Secale cereale)	14	114 Willow (S. cordiophylla)	38	162 Waterlily (N. lotus)	56
56 Ryegrass (Lolium multiflorum)	14	115 Willow (S. viminalis)	38	163 Waterlily (N. odorata)	84
57 Ryegrass (L. perenne)	14	116 Juglandaceae		164 Ranunculaceae	
58 Teosinte (Euchlaena mexicana)	20	117 Hickory (Carya spp) ⁵	32	165 Anemone (Anemone caroliniana)	16
59 Timothy (Phleum pratense)	14, 42	118 Walnut (Juglans spp) ⁶	32	166 Anemone (A. hortensis)	16
60 Wheat (Triticum aestivum)	42	119 Walnut (J. californica)	34	167 Buttercup (Ranunculus bulbosus)	14, 16
61 Wheat (T. durum)	28			168 Buttercup (R. repens)	32
62 Wheatgrass (Agropyron cristatum)	14, 28, 42			169 Christmas rose (Helleborus niger)	32
63 Cyperaceae				170 Clematis (Clematis hybrida)	16
64 Sedge (Carex hirta)	112			171 Clematis (C. paniculata)	16, 48, 64
65 Sedge (C. panicea)	32			172 Columbine (Aquilegia canadensis)	14
66 Palmae				173 Columbine (A. vulgaris)	14
67 Coconut (Cocos nucifera)	32			174 Larkspur (Delphinium ajacis)	16
68 Date (Phoenix dactylifera)	36			175 Marsh marigold (Caltha palustris)	32, 48, 56
69 Palmetto (Sabal palmetto)	36				

/1/ Spp: banksiana, bungeana, echinata, flexilis, jeffreyi, longifolia, murrayana, nigra, palustris, parviflora, peuce, pinaster, ponderosa, resinosa, rigida, sylvestris, strobilus, tabulaeformis, thunbergii, virginiana. /2/ Spp: abies, glauca, mariana, pungens, sitchensis. /3/ Spp: candidum, elegans, giganteum, longiflorum, pardalinum, regale, speciosum. /4/ Spp: acuminata, adenopoda, alba, angulata, angustifolia, balsamifera, canadensis, candicans, canescens, cathayana, deltoidea, grandidentata, jacki, koreana, lasiocarpa, laurifolia, maximowiczii, nigra, sieboldi, tomentosa, tremula, tremuloides. /5/ Spp: alba, glabra, laneyi, ovata, ovalis. /6/ Spp: cinerea, intermedia, mandschurica, nigra, regia, rupestris, sieboldiana. /7/ Spp: caroliniana, cordata, japonica, laxifolia, orientalis, tschonoskii, turczanionovii. /8/ Spp: acutissima, alba, agrifolia, bicolor, borealis, cerrii, chrysolepis, coccinea, douglasii, dumosa, engelmannii, garayana, glandulifera, ilicifera, imbricaria, incana, lobata, macrocarpa, marylandica, michauxii, montana, nigra, palustris, pontica, prinoides, prinus, robur, stellata, tomentosa, velutina. /9/ Spp: campestris, carpinifolia, glabata, fulva, japonica, laciniata, laevis, procera, pumila, racemosa.

73. CHROMOSOME NUMBERS: GYMNOSPERMS AND ANGIOSPERMS (Continued)

Extra fragment chromosomes are indicated by "f". Values are diploid chromosome numbers. Data adapted from Darlington, C. D., and Janaki Ammal, E. K., "Chromosome Atlas of Cultivated Plants," G. Allen and Unwin, Ltd., London, 1945.

Species		Number	Species		Number	Species		Number
Angiospermae: Dicotyledoneae (continued)			Angiospermae: Dicotyledoneae (continued)			Angiospermae: Dicotyledoneae (continued)		
164	Monkshood (<i>Aconitum napellus</i>)	32	216	Blackberry (<i>Rubus occidentalis</i>)	14	274	Maple (<i>Acer campestre</i>)	26
165	Peony (<i>Paeonia albiflora</i> , <i>P. moutan</i>)	10	217	Cherry (<i>Prunus avium</i>)	16, 24, 32	275	Maple (<i>A. carpinifolium</i>)	52
	Berberidaceae		218	Cherry (<i>P. cerasus</i>)	32	276	Maple (<i>A. circinatum</i>)	26
166	Barberry (<i>Berberis canadensis</i>)	28	219	Cherry-laurel (<i>P. laurocerasus</i>)	176	277	Maple (<i>A. griseum</i> , <i>A. negundo</i>)	26
167	Barberry (<i>B. vulgaris</i>)	28	220	Chokeberry (<i>P. virginiana</i>)	32	278	Maple (<i>A. platanoides</i>)	26, 78
168	Mahonia (<i>Mahonia aquifolium</i>)	28	221	Crabapple (<i>Malus asiatic</i> , <i>M. baccata</i>)	34	279	Maple (<i>A. pseudoplatanus</i>)	52
169	Nandina (<i>Nandina domestica</i>)	20	222	Flowering almond (<i>Prunus triloba</i>)	64	280	Maple (<i>A. rubrum</i>)	78, 104
	Magnoliaceae		223	Hawthorn (<i>Crataegus crus-galli</i>)	68	281	Maple (<i>A. saccharinum</i>)	52
170	Cucumber-tree (<i>Magnolia acuminata</i>)	76	224	Hawthorn (<i>C. cordata</i>)	72		Hippocastanaceae	
171	Magnolia (<i>M. denudata</i> , <i>M. grandiflora</i>)	114	225	Hawthorn (<i>C. oxyacantha</i>)	34	282	Horsechestnut (<i>Aesculus hippocastanum</i>)	40
172	Magnolia (<i>M. soulangeana</i>)	76	226	Loquat (<i>Eriobotrya japonica</i>)	34		Balsaminaceae	
173	Sweet bay (<i>M. virginiana</i>)	38	227	Mt. ash (<i>Sorbus americana</i>)	34	283	Balsam (<i>Impatiens balsamina</i>)	14
174	Yellow-poplar (<i>Liriodendron tulipifera</i>)	38	228	Peach (<i>Prunus persica</i>)	16	284	Jewelweed (<i>I. biflora</i>)	20
	Calycanthaceae		229	Pear (<i>Pyrus communis</i>)	34, 51		Vitaceae	
175	Allspice (<i>Chimonanthus fragrans</i>)	22	230	Plum (<i>Prunus domestica</i>)	48	285	Grape (<i>Vitis labrusca</i>)	38
176	Sweet-shrub (<i>Calycanthus floridus</i>)	22	231	Quince (<i>Cydonia oblonga</i>)	34	286	Grape (<i>V. rotundifolia</i>)	40
	Annonaceae		232	Raspberry (<i>Rubus idaeus</i>)	14, 21, 28	287	Grape (<i>V. vinifera</i>)	38, 57, 76
177	Cherimoya (<i>Annona cherimola</i>)	14	233	Raspberry (<i>R. strigosus</i>)	14		Tiliaceae	
178	Custard-apple (<i>A. reticulata</i>)	14	234	Rose (<i>Rosa multiflora</i>)	14	288	Basswood (<i>Tilia spp</i>) ¹⁰	82
179	Papaw (<i>Asimina triloba</i>)	18	235	Spiraea (<i>Spiraea japonica</i>)	18	289	Basswood (<i>T. amurensis</i>)	164
	Lauraceae		236	Strawberry (<i>Fragaria virginiana</i>)	56		Malvaceae	
180	Avocado (<i>Persea americana</i>)	24	237	Strawberry (<i>F. vesca</i>)	14	290	Cotton (<i>Gossypium barbadense</i>)	52
181	Camphor-tree (<i>Cinnamomum camphora</i>)	24		Leguminosae		291	Cotton (<i>G. hirsutum</i>)	52
182	Cinnamon (<i>C. zeylanicum</i>)	24	238	Alfalfa (<i>Medicago sativa</i>)	32	292	Hollyhock (<i>Althaea rosea</i>)	42, 56
183	Sweet-bay (<i>Laurus nobilis</i>)	42	239	Bean (<i>Phaseolus lunatus</i> , <i>P. vulgaris</i>)	22	293	Mallow (<i>Malva sylvestris</i>)	42
	Papaveraceae		240	Broadbean (<i>Vicia faba</i>)	12	294	Okra (<i>Hibiscus esculentus</i>)	72, 130
184	Poppy (<i>Eschscholtzia californica</i>)	12	241	Clover (<i>Trifolium aureum</i>)	14		Theaceae	
185	Poppy (<i>Papaver orientale</i>)	42	242	Clover (<i>T. incarnatum</i> , <i>T. pratense</i>)	14	295	Camellia (<i>Camellia japonica</i>)	30
186	Poppy (<i>P. rhoeas</i>)	14	243	Clover (<i>T. repens</i>)	32	296	Tea (<i>Thea sinensis</i>)	30
187	Poppy (<i>P. somniferum</i>)	22	244	Lentil (<i>Lens esculenta</i>)	14		Violaceae	
	Capparidaceae		245	Lespedeza (<i>Lespedeza striata</i>)	22	297	Pansy (<i>Viola tricolor</i>)	26
188	Caperbush (<i>Capparis spinosa</i>)	38	246	Locust (<i>Robinia pseudoacacia</i>)	20	298	Violet (<i>V. arvensis</i>)	34
189	Spider flower (<i>Cleome spinosa</i>)	20	247	Lupine (<i>Lupinus angustifolius</i>)	40	299	Violet (<i>V. odorata</i>)	20
	Cruciferae		248	Lupine (<i>L. luteus</i>)	46		Passifloraceae	
190	Cabbage (<i>Brassica oleracea</i> var.)	18	249	Pea (<i>Pisum sativum</i>)	14	300	Granadilla (<i>Passiflora quadrangularis</i>)	18
191	Candytuft (<i>Iberis amara</i>)	14, 16	250	Peanut (<i>Arachis hypogaea</i>)	40	301	Map pop (<i>P. incarnata</i>)	18
192	Candytuft (<i>I. sempervirens</i>)	22, 44	251	Redbud (<i>Cercis canadensis</i>)	12	302	Passion fruit (<i>P. edulis</i>)	18
193	Radish (<i>Raphanus sativus</i>)	18	252	Silktree (<i>Albizia julibrissin</i>)	26		Begoniaceae	
194	Shepherd's purse (<i>Capsella bursa-pastoris</i>)	16, 32	253	Soybean (<i>Glycine soja</i>)	40	303	Begonia (<i>Begonia carinata</i>)	42
195	Turnip (<i>Brassica rapus</i>)	20	254	Sweetclover (<i>Melilotus officinalis</i>)	16	304	Begonia (<i>B. margaritae</i>)	52
196	Wallflower (<i>Cheiranthus cheiri</i>)	14	255	Sweetpea (<i>Lathyrus odoratus</i>)	14		Cactaceae	
197	Watercress (<i>Nasturtium officinale</i>)	32, 48, 64	256	Oxalidaceae		305	Cactus (<i>Echinocereus angusticeps</i>)	22
	Droseraceae		257	Sorrel (<i>Oxalis acetosella</i>)	22	306	Cactus (<i>E. engelmannii</i>)	44
198	Sundew (<i>Drosera anglica</i>)	40	258	Tropaeolaceae		307	Cactus (<i>Zygocactus truncatus</i>)	24
199	Sundew (<i>D. intermedia</i>)	20	259	Nasturtium (<i>Tropaeolum majus</i>)	28		Nyssaceae	
200	Venus' fly-trap (<i>Dionaea muscipula</i>)	30	260	Linaceae		308	Tupelo (<i>Nyssa sylvatica</i>)	44
	Crassulaceae		261	Flax (<i>Linum usitatissimum</i>)	30		Myrtaceae	
201	Kalanchoe (<i>Kalanchoe aromatica</i>)	34	262	Rutaceae		309	Eucalyptus (<i>Eucalyptus globulus</i>)	20
202	Kalanchoe (<i>Kalanchoe spp</i>)	500	263	Grapefruit (<i>Citrus paradisi</i>)	18, 27, 36	310	Guava (<i>Psidium guajava</i>)	22
203	Sedum (<i>Sedum pusillum</i>)	8	264	Lemon (<i>C. limonia</i>)	18, 36	311	Myrtle (<i>Myrtus communis</i>)	22
	Saxifragaceae		265	Lime (<i>C. aurantifolia</i>)	27		Oenotheraceae	
204	Currant (<i>Ribes americanum</i> , <i>R. nigrum</i>)	16	266	Orange (<i>C. aurantium</i>)	18	312	Fuchsia (<i>Fuchsia rosea</i>)	44
205	Deutzia (<i>Deutzia crenata</i>)	130	267	Orange (<i>C. sinensis</i>)	45	313	Fuchsia (<i>F. splendens</i>)	22
206	Deutzia (<i>D. gracilis</i>)	26		Euphorbiaceae		314	Primrose (<i>Oenothera biennis</i>)	14
207	Gooseberry (<i>Ribes grossularia</i>)	16	268	Castor-bean (<i>Ricinus communis</i>)	20	315	Primrose (<i>O. pumila</i>)	28
208	Hydrangea (<i>Hydrangea paniculata floribunda</i>)	72	269	Euphorbia (<i>Euphorbia splendens</i>)	36		Umbelliferae	
209	Hydrangea (<i>H. quercifolia</i>)	36	270	Poinsettia (<i>E. pulcherrima</i>)	28	316	Caraway (<i>Carum carvi</i>)	20
	Hamamelidaceae		271	Tung oil tree (<i>Aleurites fordii</i>)	22	317	Carrot (<i>Daucus carota</i>)	18
210	Sweetgum (<i>Liquidambar styraciflua</i>)	30	272	Callitrichaceae		318	Celery (<i>Apium graveolens</i>)	22
211	Witch-hazel (<i>Hamamelis virginiana</i>)	24	273	Callitriche (<i>Callitriche autumnalis</i>)	6	319	Dill (<i>Anethum graveolens</i>)	22
	Platanaceae			Buxaceae		320	Parsnip (<i>Pastinaca sativa</i>)	22
212	Aspen (<i>Platanus acerifolia</i>)	42	274	Boxwood (<i>Buxus sempervirens</i>)	28	321	Parsley (<i>Petroselinum sativum</i>)	23
213	Sycamore (<i>P. occidentalis</i>)	42	275	Aquifoliaceae			Cornaceae	
	Rosaceae		276	Holly (<i>Ilex aquifolium</i>)	40	322	Dogwood (<i>Cornus controversa</i>)	20
214	Almond (<i>Prunus amygdalus</i>)	16	277	Holly (<i>I. opaca</i>)	36	323	Dogwood (<i>C. florida</i>)	22
215	Apple (<i>Pyrus malus</i>)	34	278	Winterberry (<i>I. verticillata</i>)	36	324	Dogwood (<i>C. mas</i>)	18
			279	Yapon (<i>I. vomitoria</i>)	40		Ericaceae	
						325	Blueberry (<i>Vaccinium atrococcum</i>)	48
						326	Blueberry (<i>V. angustifolium</i>)	48
						327	Rhododendron (<i>Rhododendron spp</i>) ¹¹	26

/10/ Spp: cordata, europaea, glabra, neglecta, oliveri, platyphylos. /11/ Spp: arborescens, carolinianum, catawbiense, maximum, ponticu, roseum, vesey, viscosum.

73. CHROMOSOME NUMBERS: GYMNOSPERMS AND ANGIOSPERMS (Concluded)

Extra fragment chromosomes are indicated by "f". Values are diploid chromosome numbers. Data adapted from Darlington, C. D., and Janaki Ammal, E. K., "Chromosome Atlas of Cultivated Plants," G. Allen and Unwin, Ltd., London, 1945.

Species	Number	Species	Number	Species	Number
Angiospermae: Dicotyledoneae (continued)		Angiospermae: Dicotyledoneae (continued)		Angiospermae: Dicotyledoneae (concluded)	
328 Rhododendron (Rhododendron calendulaceum)	52	357 Labiatae		382 Caprifoliaceae	
329 Primulaceae		358 Coleus (Coleus blumei)	24	383 Cranberry (Viburnum trilobum)	18
330 Cyclamen (Cyclamen persicum)	48, 84	359 Lavender (Lavandula officinalis)	54	384 Elder (Sambucus canadensis)	36
331 Primrose (Primula vulgaris)	22	360 Peppermint (Mentha piperita officinalis)	72, 84	385 Honeysuckle (Lonicera sempervirens)	36
332 Plumbaginaceae		361 Peppermint (M. piperita vulgaris)	68, 72	386 Cucurbitaceae	
333 Plumbago (Plumbago europaea)	14	362 Rosemary (Rosmarinus officinalis)	24	387 Cucumber (Cucumis sativus)	14
334 Ebenaceae		363 Thyme (Thymus serpyllum)	24	388 Gourd, bottle (Lagenaria vulgaris)	22
335 Persimmon (Diospyros kaki)	90	364 Solanaceae		389 Pumpkin (Cucurbita pepo)	40
336 Persimmon (D. virginiana)	60, 90	365 Eggplant (Solanum melongena)	24	390 Squash (C. maxima, C. moschata)	40
337 Ash (Fraxinus americana)	46	366 Pepper (Capsicum annuum)	24	391 Watermelon (Citrullus vulgaris)	22
338 Ash (F. chinensis)	138	367 Petunia (Petunia violacea)	14	392 Campanulaceae	
339 Forsythia (Forsythia suspensa)	28	368 Nightshade (Atropa belladonna)	72	393 Canterbury bell (Campanula medium)	34
340 Forsythia (F. viridissima)	28	369 Potato (Solanum tuberosum)	48	394 Cardinal flower (Lobelia cardinalis)	14
341 Fringe-tree (Chionanthus virginica)	46	370 Tobacco (Nicotiana tabacum)	48	395 Compositae	
342 Jasmine (Jasminum nudiflorum)	52	371 Tomato (Lycopersicon esculentum)	24	396 Aster (Aster laevis)	54
343 Lilac (Syringa vulgaris)	46-48	372 Scrophulariaceae		397 Aster (A. multiflorus)	10
344 Olive (Olea europaea)	46	373 Foxglove (Digitalis purpurea)	56	398 Chrysanthemum (Chrysanthemum frutescens)	27
345 Osmanthus (Osmanthus fortunei)	44	374 Mullein (Verbascum thapsus)	32	399 Chrysanthemum (C. leucanthemum)	36
346 Privet (Ligustrum vulgare)	46	375 Snapdragon (Antirrhinum majus)	16	400 Chrysanthemum (C. maximum)	90
347 Asclepiadaceae		376 Bignoniaceae		401 Cosmos (Cosmos bipinnatus)	24
348 Milkweed (Asclepias incarnata)	22	377 Catalpa (Catalpa bignonioides)	40	402 Dahlia (Dahlia variabilis)	64
349 Wax plant (Hoya carnosa)	22	378 Trumpet vine (Campsis radicans)	40	403 Dandelion (Taraxacum officinale)	24
350 Convolvulaceae		379 Gesneriaceae		404 Guayule (Parthenium argentatum)	35, 38, 54, 72, 108-111
351 Cypress vine (Ipomoea sloteri)	58	380 African violet (Saintpaulia ionantha)	28	405 Lettuce (Lactuca sativa)	18
352 Moonflower (I. speciosum)	30	381 Plantaginaceae		406 Marigold (Tagetes erecta)	24
353 Morning glory (I. purpurea)	30	382 Plantain (Plantago lanceolata)	24, 96	407 Sunflower (Helianthus annuus)	34
354 Sweetpotato (I. batatas)	90	383 Plantain (P. major)	12	408 Yarrow (Achillea millefolium)	36, 54
355 Polemoniaceae		384 Rubiaceae		409 Zinnia (Zinnia elegans)	24
356 Phlox (Phlox divaricata)	14+0-if	385 Button bush (Cephalanthus occidentalis)	44		
357 Phlox (P. drummondii)	14, 28	386 Cinchona (Cinchona ledgeriana)	40		
358 Phlox (P. maculata)	14	387 Coffee (Coffea arabica)	22		
359 Boraginaceae		388 Gardenia (Gardenia intermedia)	22		
360 Borage (Borago officinalis)	16				
361 Myosotis (Myosotis alpestris)	24, 48, 72				
362 Myosotis (M. palustris)	22, 64				

74. CHROMOSOME NUMBERS: FUNGI

Values are haploid numbers taken from the 1940-1952 literature. Because of the difficulty in obtaining accurate counts (mainly at meiosis) of the typically small fungi chromosomes, values in many cases should be considered estimates. Reports of two chromosomes for haploid numbers have been questioned and, therefore, are not listed.

Species	Number	Species	Number	Species	Number
1 Absidia apinosa	12	29 Gymnosporangium nidus-avis	8	57 Peziza micropus	8
2 Achlya bisexualis	3	30 G. transformans	8	58 P. ochracea	6
3 A. megasperma	5	31 Helotium citrinum	6	59 P. saniosa	8
4 A. recurva	4	32 Helvella atra	6	60 P. succosa	8
5 Albugo evolvuli	8	33 H. crispa	6	61 P. venosa	6
6 A. portulacae	8	34 H. lacunosa	6	62 P. vesiculosa	8
7 Allomyces arbuscula ¹	16	35 Humarina leucoloma	8	63 Phaeobulgarina inquinans	6
8 A. cystogenus	14	36 Hypomyces solani	6	64 Phyllactinia corylea	8
9 A. javanicus javanicus	13-21	37 Isoachlya intermedia	6	65 Phytophthora himalayensis	3
10 A. javanicus macrogynus ²	28	38 Lamprospora constellatio	6	66 Plasmopara viticola	14-16
11 Amanita caesaria	4	39 L. haemastigma	6	67 Pyronema omphalodes	6, 12
12 Ascobolus magnificus	8	40 Leotia lubrica	8	68 Rhizophydium coronum	6, 8
13 A. sterocarius	16	41 Lepiota lenticularis	4	69 Saprolegnia litoralis	7
14 Aspergillus nidulans	4	42 Melastiza charteri	4	70 Schizophyllum commune	3
15 Calonectria rigidiuscula	7	43 Nectria episphearia	7	71 Sclerotinia trifoliorum	6, 8
16 Ciliaria hirta	4	44 N. flava	4	72 Scodellina leporina	8
17 Coleosporium helianthi	8	45 Neurospora crassa	7	73 Septobasidium spp	5
18 C. sidae	8	46 N. sitophila	7	74 Sepultaria arenicola	8
19 C. vernoniae	8	47 N. tetrasperma	6, 7	75 Sordaria fimicola	8
20 Cudonia circinans	6	48 N. sp (8-spored)	7	76 Spathularia clavata	6
21 Dermatozon carpon aquaticum	8	49 Olpidopsis achlyae	6	77 Stigmata geranii	4
22 Dictyostelium discoideum	7	50 Otidea vitellina	8	78 Taphrina deformans	4
23 Eremascus albus	6	51 Patella albida	8	79 Thekopsora hydrangeae	4
24 Gibberella lateritium	6	52 P. melaloma	4, 6	80 Thraustotheca primoachlya	5
25 G. roseum	6	53 P. scutellata	6	81 Torula utilis	4
26 Glomerella cingulata	4	54 Paxina acetabulum	6	82 Tremellodon gelatinosum	4
27 Gymnosporangium clavipes	8	55 P. hispida	8	83 Uromyces aloes	6
28 G. juniperi-virginianae	8	56 Penicillium cyclopium	6-7	84 Venturia inaequalis	4, 6

/1/ N = 8-32 in various isolates. /2/ N = 50 or more in certain polyploid isolates.

75. CELL DIVISION FREQUENCY: MICROORGANISMS

Part I: BACTERIA AND VIRUSES

Generation time for bacteria is the average interval between cell divisions.

Organism	Culture Medium	Temperature °C	Generation Time min	Organism	Culture Medium	Temperature °C	Generation Time min
1 Aerobacter aerogenes	Broth or milk	37	16-18	52 Phytomonas tabacum	Broth	25	81
2	Glucose + peptone	37	17.3	53 Proteus vulgaris	Broth	37	21.5
3	Peptone	37	22-30	54	Peptone + phosphate	37	40
4	Synthetic	37	29-44	55 Pseudomonas fluorescens	Broth	30	40
5 Azotobacter spp	Mineral salts + sugar	25-30	240-348	56	Glucose broth	37	34-34.5
6 A. chroococcum	Glucose broth	37	27-39	57	Broth	37	34
7	Sugar + urea	28	74	58	Glucose broth	37	31
8 Bacillus cereus	Broth	37	18.8	59	Lactose broth	37	34
9	Glucose broth	37	17-24.5	60 Rhizobium japonicum	Mineral salts + yeast + mannitol	25	344-461
10 B. megatherium	Broth	30	31	61 R. leguminosarum	Mineral salts + mannitol	25	79-187
11 B. mycoides	Broth	37	28	62 R. meliloti	Mineral salts + yeast + mannitol	25	107
12 B. subtilis	Glucose broth	55	18.3	63 R. trifolii	Mineral salts + yeast + mannitol	25	101
13 B. thermophilus	Broth	54.5	16	64 Salmonella enteritidis	Broth	42	21.5
14 Clostridium amylobacter	Tryptophan + broth	37	51	65 S. paratyphi	Broth	37	23
15	Corn mash	37	35	66	Peptone	37	28
16 C. botulinum	Glucose broth	37	35	67 S. suispestifer	Broth	37	26
17 C. welchii	Milk	37	35	68 S. typhi	Bile + pus	37	24.5
18 Corynebacterium diphtheriae	Serum + glucose broth	37	29	69	Broth	37	23.5
19 C. pseudodiphtheriae	Broth	37	20.5	70	Glucose broth	37	29
20 Diplococcus mucosus	Milk	37	33	71	Glucose + peptone	37	33
21 D. pneumoniae I	Broth	37	30	72 Serratia marcescens	Milk	37	37
22	Serum	37	23	73 Shigella dysenteriae	Milk	37	23
23	Serum + broth	37	57	74	Peptone + phosphate	37	37
24 D. pneumoniae II	Broth	37	42	75 Spirochaeta spp	Modified thioglycolate	37	528
25	Glucose broth	37	71-94	76 Staphylococcus albus	Glucose broth	37	24-25
26	Serum + broth	37	17	77 S. aureus	Broth	37	27-30
27 Erwinia carotovora	Broth	37	16	78	Glucose broth	37	32
28	Glucose broth	37	12.5	79 Streptococcus fecalis	Glucose-citrate broth	37	27
29 E. amylovora	Lactose broth	37	16	80	Milk	37	26.5
30 Escherichia coli	Milk	37	16	81 S. hemolyticus	Beef heart broth	37	32
31	Lactose broth	37	66-87	82	Glucose broth	37	26
32	Milk	37	41-75	83	Glucose serum broth	37	34
33 E. coli communior	Glucose milk	37	39-74	84 S. lactis	Glucose milk	37	26
34 Lactobacillus acidophilus	Milk	37	50	85	Lactose broth	30	48
35 L. bulgaricus	Peptone milk	37	38-40	86	Milk	37	26
36	Tomato juice + milk	37	37	87	Peptone milk	37	37
37	Yeast extract	37	38	88	Milk	37	27
38	Milk	25	83	89 S. liquefaciens	Glucose milk	37	35-37
39	Wort	45	67	90 S. mastitidis	Milk	37	27
40 L. casei	Yeast extract	28	792-932	91 Treponema pallidum	Rabbit skin	37	1800
41 L. delbrückii	Synthetic	37	24.4	92	Rabbit testes	37	1980
42 L. pentosaceticus	Broth + blood	23-25	165	93 Vibrio comma	Broth	37	21.2-38
43 Mycobacterium tuberculosis ¹	Broth	25	98	94 V. costatus	Broth	27	42
44 Pasteurella leipsetica	Broth	23-25	95	95 Viruses			
45 Phytomonas campestris	Broth	25	160	96 Influenza A (PR-8)	Allantoic membrane ²	37	330-510 ³
46 P. campetere	Broth	25	150	97 A (5 strains)	Allantoic membrane ²	37	300-360 ³
47 P. glycineum	Broth	25	138	98 B (3 strains)	Allantoic membrane ²	37	480-600 ³
48 P. phaseoli	Bean broth	25	82	98 Swine	Allantoic membrane ²	37	360 ³
49	Broth	23-25					
50	Glucose broth						
51	Broth						

/1/ Human strain H-37. /2/ Chick embryo. /3/ For viral agents generation time is the time required for infected cells to release new virus.

Part II: PROTOZOA

Organism	Substrate	Temperature °C	Cell Division per da	Organism	Substrate	Temperature °C	Cell Division per da
1 Astasia	Tryptophan + Ac ¹	25	3.1	11 Paramecium aurelia	Lettuce + bacteria	20 ¹	0.72 ⁴
2 Chilomonas paramecium	NaAc ¹ + mineral salts	24	3.5	12 P. caudatum	Mineral salts + bacteria ⁵	25-28	1.8
3 Didinium nasutum	Hopkin's + paramedium	21	3.6	13	Oat medium + bacteria ⁶	26	2.3
4 Euglena gracilis	In dark, no Ac ¹	10	0.03	14 Polytomella uvella	Aerated peptone	22	4.4
5	In dark + Ac ¹	23	0.47	15	Non-aerated peptone	22	1.8
6	Wheat infusion	25	3.5	16 Stentor coeruleus	Peter's + ciliates	19	0.6-0.9
7 Glaucoma pyriformis	Yeast extract	25	6.1 ²	17	Modified Peter's ⁵	18-20	0.7-2.1
8	Yeast extract	24.2	6.9	18	Hetherington's ⁶	22	0.65
9	Yeast + yeast extract ³	25.2	7.6-8	19 Stylonychia pustulata		25?	4.5-5
10 Leucophrys patula	Glaucoma	25	3.7	20 Tetrahymena geleii		24	5.7-10.9

/1/ Acetate. /2/ Phelps strain. Hetherington's strain. 6.4 div./da. /3/ Or peptone. /4/ At 28°C, 2 div./da. /5/ B. subtilis. /6/ Plus ciliates.

76. GENETICS OF PARAMECIUM

Part I: PARAMECIUM AURELIA (After Beale.)

Nine varieties with 17 mating types have been found. Only one mating type has been found in Variety 7. Values in the table are maximum percentages of conjugating pairs formed in mixtures of two types of paramecia. "Inc." means incomplete mating reaction, not leading to conjugation; when Inc. is enclosed in parentheses (Inc.) it indicates a weak, tentative reaction involving only a small proportion of the animals. Intervarietal conjugation gives rise to hybrid nonviability or low viability, or low viability of F₂ or back-cross generations.

Group	Variety	A										B					
		Mating Type	I	II	V	VI	IX	X	XIII	XVII	XVIII	III	IV	VII	VIII	XI	XII
A	1	I	0	95	0	0	0	40	0	0	0	0	0	0	0	0	0
		II		0	1	0	40	0	10	0	0	0	0	0	0	0	0
	3	V			0	95	0	0	0	0	0	0	0	0	0	0	0
		VI				0	0	0	(Inc.)	0	0	0	0	0	0	0	0
	5	IX					0	95	0	0	0	0	0	0	0	0	0
		X						0	(Inc.)	0	0	0	0	0	0	0	0
B	7	XIII							0	0	0	0	0	0	0	0	(Inc.)
	9	XVII								0	95	0	0	0	0	0	0
		XVIII									0	0	0	0	0	0	0
	2	III										0	95	0	0	0	0
		IV											0	0	0	0	0
	4	VII												0	95	0	95 Inc.
		VIII													0	95	0
	6	XI														0	0
		XII														0	0
	8	XV															0
		XVI															95

Part II: PARAMECIUM BURSARIA (After Sonneborn.)

Six varieties with 23 mating types have been found. Only one mating type has been found in Variety V. In mixtures of the two mating types represented on the corresponding row and column, + = occurrence of conjugation, - = no conjugation. Intervarietal conjugation between varieties II and IV is lethal.

Variety	Mating Type	I				II								III				IV		V		VI			
		A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	
I	A	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	B	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	C	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	D	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
II	E					-	+	+	+	+	+	+	+	-	-	-	-	+	-	-	-	-	-	-	
	F					+	-	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	
	G					+	+	-	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	
	H					+	+	+	-	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	
	J					+	+	+	+	-	+	+	+	-	-	-	-	-	-	-	-	-	-	-	
	K					+	+	+	+	+	-	+	+	-	-	-	-	+	-	-	-	-	-	-	
	L					+	+	+	+	+	+	+	+	-	-	-	-	+	-	-	-	-	-	-	
	M					+	+	+	+	+	+	+	+	-	-	-	-	+	-	-	-	-	-	-	
III	N													-	+	+	+	-	-	-	-	-	-	-	
	O													+	-	+	+	-	-	-	-	-	-	-	
	P													+	+	-	+	-	-	-	-	-	-	-	
	Q													+	+	+	-	-	-	-	-	-	-	-	
IV	R																	+	+	-	-	-	-	-	
	S																	+	-	-	-	-	-	-	
V	T																			-	-	-	-	-	
VI	U																				-	+	+	+	
	V																				+	-	+	+	
	W																				+	+	-	+	
	X																				+	+	+	-	

Part III: PARAMECIUM CAUDATUM (After Gilman.)

Sixteen varieties with 31 mating types, but only one in Variety 10, have been found. In mixtures of the two mating types represented on the corresponding row and column, + = strong mating reaction and conjugation, ± = mating reaction but no conjugation, - = no mating reaction or conjugation.

Variety	Mating Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
		I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII	XIV	XV	XVI
1	I	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	II	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	III	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
	IV	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-
3	V	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
	VI	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-
4	VII	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
	VIII	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
5	IX	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
	X	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
6	XI	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
	XII	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
7	XIII	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
	XIV	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
8	XV	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-
	XVI	-	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-
9	XVII	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
	XVIII	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-
10	XX ¹	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
	XXI	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-
11	XXII	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-
	XXIII	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
12	XXIV	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
	XXV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-
13	XXVI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
	XXVII	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
14	XXVIII	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	XXIX	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
15	XXX	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	XXXI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	XXXII	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	XXXIII	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

1/ One mating type XIX has been found.

76. GENETICS OF PARAMECIUM (Concluded)

Part V: PARAMECIUM MULTIMICRONUCLEATUM

(Parts IV, V and VI after Wichterman.)
+ = mating reaction and conjugation; - = none in mixtures of two mating types represented in the corresponding row and column.

Mating Type	I	II	III	IV
I	-	+	+	+
II	+	-	+	+
III	+	+	-	+
IV	+	+	+	-

Part VII: INHERITANCE OF MATING TYPES

Part IV: PARAMECIUM CALKINSI

+ = mating reaction and conjugation; - = none in mixtures of two mating types represented in the corresponding row and column.

Variety	Mating Type	I	II	III	IV
1	I	-	+	-	-
	II	+	-	-	-
2	III	-	-	-	+
	IV	-	-	+	-

Part VI: PARAMECIUM TRICHIMUM

+ = mating reaction and conjugation; - = none in mixtures of two mating types represented in the corresponding row and column.

Mating Type	I	II	III
I	-	+	+
II	+	-	+
III	+	+	-

Section 1: Paramecium aurelia (After Sonneborn.)

a. Analysis of 4 caryonides from individual pairs of conjugants.

No. of Pairs	Number of Caryonides	I	II
1	4	0	0
18	3	1	1
21	2	2	2
13	1	3	3
3	0	4	4

b. Analysis of the two sister caryonides from each ex-conjugant.

Number of Ex-conjugants	Number of Caryonides	I	II
35	2	0	0
70	1	1	1
34	0	2	2

/1/ Each ex-conjugant contains two macronuclei derived from a single fusion nucleus. When the ex-conjugant divides into two daughter cells, each cell contains one of the two macronuclei. All descendants of each daughter cell constitute a caryonide.

Section 2: Paramecium bursaria (After Jennings.)

Parental Types (Mating Types of the Conjugants)	Number of Pairs Yielding Clones of the Parental Mating Types	Numbers Yielding Clones of Non-Parental Mating Types
A X B	103	6
A X C	39	22
A X D	66	14
B X C	89	1
B X D	64	38
C X D	120	4
L X M	44	43
Total:	525	128

Part VIII: DIFFERENCES BETWEEN VARIETIES: PARAMECIUM BURSARIA

Differences	Variety I	Variety II	Variety III
1 Time of day or night when animals can undergo mating reaction.	Daytime.	Daytime.	Any time of day or night.
2 Length of time of conjugation (at 26.5°C).	20-22 hours.	36 or more hours.	
3 Chromosomes	Intermediate between varieties II and III.	Thin and short.	Generally thick and long.

Part IX: GEOGRAPHICAL DISTRIBUTION OF VARIETIES

Section 1: <i>Paramecium aurelia</i> ¹						Section 2: <i>Paramecium bursaria</i> ²						Section 3: <i>Paramecium caudatum</i> ³								
Variety	North America	South America	Western Europe	Japan	India	Variety	U.S.A.	China	Japan	Russia	Central, Western Europe	Variety	U.S.A.	Japan	France	Variety	U.S.A.	Japan	France	
1	X	X	X	X	.	I	X	X	X	.	.	1	X	X	.	.	9	X	.	.
2	X	X	X	.	.	II	X	.	.	.	.	2	X	.	.	.	10	X	.	.
3	X	.	.	.	.	III	X	.	.	.	.	3	X	X	.	.	11	X	.	.
4	X	X	.	X	.	IV	.	.	.	X	.	4	X	.	.	.	12	.	X	.
5	X	.	.	.	.	V	.	.	.	X	.	5	X	.	.	.	13	.	X	.
6	X	.	.	.	X	VI	.	.	.	.	X	6	X	.	.	.	14	X	.	.
7	X	.	.	.	.		.	.	.	.	.	7	X	.	.	.	15	.	.	X
8	X	.	.	.	.		.	.	.	.	.	8	X	.	.	.	16	.	.	X
9	.	.	X	.	.		.	.	.	.	.		.	.	.	.

/1/ After Sonneborn, Beale, and Schneller.

/2/ After Jennings, Opitz, and Chen.

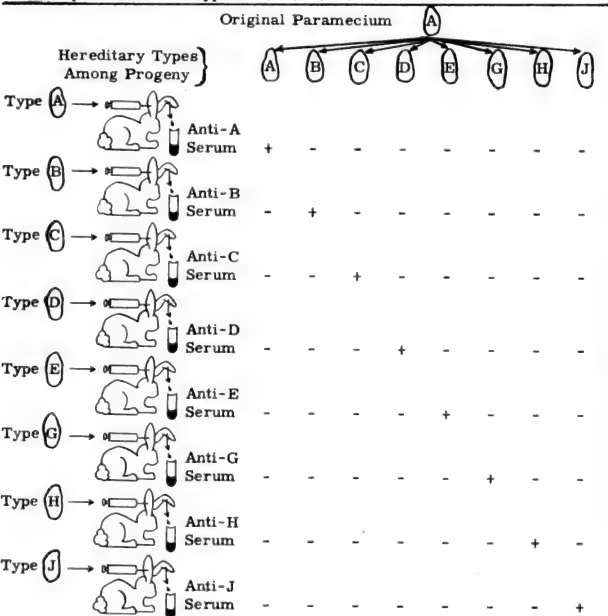
/3/ After Gilman.

/1/ After Sonneborn, Beale, and Schneller. /2/ After Jennings, Opitz, and Chen. /3/ After Gilman.

77. THE ANTIGENIC TYPES: PARAMECIUM AURELIA (RACE 51)

(After Sonneborn.)

Serum taken from a rabbit repeatedly injected with paramecia paralyzes paramecia of the same strain. The serum may or may not have a paralyzing effect on other strains. If a second rabbit is injected with a resistant strain, the serum obtained will paralyze paramecia of the second strain but not the first. This indicates interaction between paramecia antigens of rabbit antibodies. Each antigenically distinct strain is called a serotype. A culture of one serotype, derived from a single ancestral cell, may give rise to cells of different hereditary serotypes. The accompanying diagram illustrates a single cell of race 51 (serotype A) giving rise to the original A and seven distinctly different serotypes, B, C, D, E, G, H and J.



78. GENETIC SYSTEM INVOLVED IN CONTROL OF ANTIGENIC TRAITS: PARAMECIUM AURELIA (RACE 51) (After Beale.)

In Figure 1, the two conjugants do not exchange cytoplasm. This is normal. The 51A parent gives rise to 51A animals, whereas 51B parent gives rise to 51B animals. Inheritance therefore appears to be cytoplasmically determined. If a substantial amount of cytoplasm is exchanged between two mates, both would produce either type 51A or type 51B. In Figure 2, small amounts of cytoplasm are exchanged. One mate produces type 51A, while the other produces mostly type 51B and some type 51A. Evidence indicates that antigenic types differ only in cytoplasmic factors.

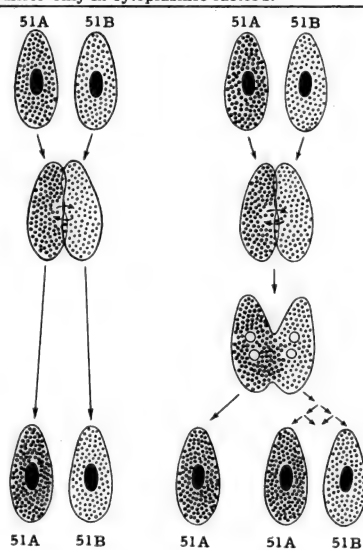


Fig. 1: Conjugation without Cytoplasmic Exchange

Fig. 2: Conjugation with Cytoplasmic Exchange

79. BLOOD GROUPS AND FACTORS: DISTRIBUTION IN VARIOUS POPULATIONS

Values are per cent of the population.

Group or Factor		Population														
General	Differentiated	American Indian ¹	Arabian, Baghdad	Australian, Aborigine	Chinese	Egyptian, Cairo	English	Eskimo, S.W. Greenland	German, Berlin	Hawaiian	Hindu	Italian	Japanese	Norwegian	Russian	Swedish
Blood Groups ²																
1	O	23.5-98.5	34.1	53.1	30.0	26.6	46.7	36.3	36.5	31.3	41.2	31.2		33.7	37.9	49.3
2	A	1.5-76.5	30.8	44.7	25.0	35.7	41.7	54.6	42.5	60.8	19.0	39.4	38.4		38.4	46.7
3	B	0-1.6	28.9	2.1	35.0	27.1	8.6	5.3	14.5	2.2	41.2	14.0	21.8		20.8	10.3
4	AB	0	6.2	0	10.0	10.5	3.0	3.7	6.5	0.5	8.5	5.4	8.6		7.1	5.1
Rh Positive																
7	Rh ₀	1.1		4.0	0.9	11.5	2.5	1.0	2.0		2.9	1.3	0	1.5		45.9
8	Rh ₁	40.7		39.0		25.5	19.7		19.5		35.2	23.3		15.9		0.9
9	Rh ₁ rh	7.4		14.0	60.6	39.7	35.2	34.9	35.6		32.4	37.3	37.4	35.6		22.8
10	Rh ₂	9.5		21.0	3.0	9.2	12.2	19.7	12.9		3.8	9.6	13.3	13.8		16.3
11	Rh ₂ rh	38.1		15.0	34.1	8.2	13.6	44.4	13.9		16.2	11.8	47.3	14.7		4.4
12	Rh ₂ Rh	3.1		6.0			0.1		0.4		0	0.6				0
Rh Negative																
13	rh	0		0	1.5	5.9	14.8	0	14.4		7.6	14.8	1.3	16.2		7.4
14	rh'	0		1.0	0		0.7	0	0.5		1.9	0.5	0	0.7		1.5
15	rh''	0		0	0		1.3	0	0.8			0.5	0	1.2		0.7
16	rh _y	0		0	0		0	0				0.3	0.7			0
Blood Factors (M-N Blood Groups) ³																
17	M	60.0		3.0	33.2	28.3	30.5	67.6	30.2		42.7	28.9	29.0		32.2	36.1
18	N	4.9		67.4	18.2	23.1	21.4	2.4	19.7		10.7	17.1	21.1		21.2	16.9
19	MN	35.1		29.6	48.6	48.6	48.2	30.0	50.0		46.7	53.9	49.9		46.5	47.0

/1/ Blood group data from Toba Indians (Argentina), Blackfeet (Montana), and Pueblo (New Mexico); Rh data from Mexican Indians; M-N data from U.S.A., tribe not specified. /2/ Equivalents in obsolete terminologies of Moss and Jansky are: O=Moss IV, Jansky I; A=Moss and Jansky II; B=Moss and Jansky III; AB=Moss I, Jansky IV. /3/ Other blood group systems are the P, Lutheran (Lu^a), Kell-Cellano (K, k), Lewis (Le^a, Le^b), Duffy (Fy^a, Fy^b), and Kidd (Jk^a, Jk^b). The approximate frequencies for U.S.A. whites are: P 49%; Lu^a 4%, Lu^b 96%; K 5%, k 95%; Le^a 47%, Le^b 48%; Fy^a 41%, Fy^b 59%; Jk^a 52%, Jk^b 48%.

80. HEREDITY OF BLOOD GROUPS AND FACTORS: APPLICATION IN DISPUTED PATERNITY

Children's Groups		If Parents' Groups Are:														
		OxO	OxA	OxB	AxA	AxB	BxB	OxAB	AxAB	BxAB	ABxAB	MNxMN	MNxM	MNxN	MxM	NxN
1	Can be:	O	A, O	B, O	A, A ¹	AB, O ² , A ³ , B ¹	B, O ³	A, B	A, AB, B ¹	B, AB, A ³	A, B, AB	M, N, MN	M, MN	M, MN	M	N
2	Cannot be:	A, B, AB	B, AB	A, AB	B, AB	None	A, AB, O, AB	O	O	O	O	None	N	M	M, N, N, MN	M, MN

/1/ This type not possible if either parent is genetically A/A. /2/ If one parent was genetically A/O and the other B/O, an O can result. /3/ This type not possible if one parent is genetically B/B.

81. THE Rh-Hr (CDE-cde) SYSTEM OF BLOOD FACTORS

Plus (+) indicates agglutination by antiserum; thus C+ = agglutination of red cells by anti-C (anti-rh') and presence of agglutinin C, i.e., in the red cells. Minus (-) = no reaction with antiserum and absence of agglutinin. In CDE notation, diagonal (/) separates genes contributed by one parent from those contributed by the other parent.

Phenotypes and their Frequencies ¹ ; Classified by Agglutination Reactions with Antisera		Genotypes			
1 Antiserum (Anti-D)	3 Antisera (Anti-C, D, E)	5 Antisera (Anti-C, D, E, c, e)	Wiener Terminology	Fisher-Race Terminology	Calculated Frequencies %
1	Rh ₀ (D-), negative 14.9%	rh (C-D-E-), 13.4%	rr	cde/cde	13.4
2		rh' (C+D-E-), 1.1%	r'r' (C+D-E-c-e+)	Cde/Cde	0.02
3		rh'' (C+D-E-c-e+)	r'r''	Cde/cde	1.1
4		rh''' (C-D-E+c-e-)	r''r'''	Cde/cde	0.003
5		rh'''' (C-D-E+c-e+)	r'''r''''	Cde/cde	0.4
6		rh'rh'' (rh _y) (C+D-E+), 0.02%	r'r'rh''	Cde/cde	0.02
7			r'r'rh''	Cde/cde	0.0003
8			r'r'rh''	Cde/cde	0.0001
9			r'r'rh''	Cde/cde	0.000001
10			r'r'rh''	Cde/cde	0.000001
11	Rh ₀ (D+), positive 85.1%	Rh ₀ (C-D+E-), 2.5%	R ₀ R ₀ (C-D+E-c-e+)	CDe/CDe	0.1
12			R ₀ R ₀	CDe/cde	2.4
13			R ₀ R ₀	CDe/CDe	16.9
14			R ₀ R ₀	CDe/cde	1.1
15		Rh ₁ (C+D+E-), 51.2%	R ₁ R ₁ (C+D+E-c-e+)	CDe/CDe	2.6
16			R ₁ R ₁	CDe/cde	30.6
17			R ₁ R ₀ (C+D+E-c-e+)	CDe/cde	
18			R ₁ R ₀	CDe/CDe	2.7
19			R ₁ R ₀	CDe/cde	0.2
20		Rh ₂ (C-D+E+), 16.5%	R ₂ R ₂ (C-D+E+c-e-)	CDe/CDe	1.1
21			R ₂ R ₂	CDe/cde	12.5
22			R ₂ R ₀ (C-D+E+c-e+)	CDe/cde	
23			R ₂ R ₀	CDe/CDe	13.9
24			R ₂ R ₀	CDe/cde	
25			R ₂ R ₀	CDe/cde	
26			R ₂ R ₀	CDe/cde	
27			R ₂ R ₀	CDe/cde	
28			R ₂ R ₀	CDe/cde	
29			R ₂ R ₀	CDe/cde	
30			R ₂ R ₀	CDe/cde	
31			R ₂ R ₀	CDe/cde	
32			R ₂ R ₀	CDe/cde	
33			R ₂ R ₀	CDe/cde	
34			R ₂ R ₀	CDe/cde	
35			R ₂ R ₀	CDe/cde	
36			R ₂ R ₀	CDe/cde	

/1/ Frequencies are percentages showing occurrence in American whites. The percentage of whites reacting positively to various antisera are: 70%, anti-C (anti-rh'); 85%, anti-D (anti-Rh₀); 30%, anti-E (anti-rh''); 80%, anti-c (anti-rh'); 97%, anti-e (anti-rh'').

82. GENETIC LINKAGE: MAN
Part I: COMPLETELY SEX-LINKED GENES (X-CHROMOSOME TRANSMISSION)

Mutation	Gene Symbol	Phenotypic Expression		
		Hemizygote XY	Heterozygote XX	Homozygote XX
1 Classical hemophilia	h	Severe bleeder.	Normal.	Severe bleeder.
2 Mild hemophilia	h ^m	Mild bleeder.	Occasionally slightly affected.	Unknown.
3 Plasma thromboplastin component deficiency		Severe bleeder.	Slightly affected.	Unknown.
4 Retinitis pigmentosa		Choroidoretinal degeneration.	Tapetal reflex.	Unknown.
5 Ocular albinism		Lack of pigment in globe.	Fundal changes.	Unknown.
6 Red-green color blindness	b	Color blindness.	Mildly affected.	Color blindness.
7 Hemeralopia		Night blindness with myopia.	Normal.	Unknown.
8 Megalocornea		Large cornea.	Occasionally affected.	Unknown.
9 Microphthalmia		Microphthalmia and blindness.	Normal.	Normal.
10 Choroidemia		Night blindness, constricted visual fields, blindness.	Depigmented retina.	Unknown.
11 Nystagmus		Severe nystagmus.	Slight nystagmus.	Unknown.
12 Optic atrophy		Blindness.	Occasionally blind.	Unknown.
13 Congenital retinal detachment		Retinal detachment and blindness.	Normal.	Blindness(?).
14 External ophthalmoplegia		Ophthalmoplegia, myopia, absent knee jerks.	Absent knee jerks.	Unknown.
15 Macular dystrophy		Loss of central vision.	Normal.	Unknown.
16 Childhood progressive muscular dystrophy		Muscular dystrophy.	Normal.	Unknown.
17 Peroneal atrophy		Peroneal atrophy.	Occasionally affected.	Unknown.
18 Idiocy		Idiocy with microcephaly.	Normal.	Unknown.
19 Alopecia congenita		Hairlessness.	Normal.	Unknown.
20 Anhidrotic ectodermal dysplasia		Widespread ectodermal defects.	Normal.	Unknown.
21 Ichthyosis simplex		Scaly skin.	Normal.	Scaly skin.
22 Keratosis follicularis (Lameris)		Multiple skin keratoses.	Normal.	Unknown.
23 White occipital lock of hair		White lock of hair at occiput.	Normal.	Unknown.

Part II: HOLANDRIC GENES (Y-CHROMOSOME TRANSMISSION)

Mutation	Phenotypic Expression XY	Mutation	Phenotypic Expression XY
1 Ichthyosis hystrix gravior	Bark-like skin.	4 Keratoma dissipatum	Horny papules on hands and feet.
2 Hypertrichosis of the ears.	Hairy ears.	5 Color vision anomaly	Poor color discrimination.
3 Webbed toes	Webbed toes.		

Part III: INCOMPLETELY SEX-LINKED GENES (X- and Y-CHROMOSOME TRANSMISSION)

The concept of homologous segments of the X- and Y-chromosomes has become widely disseminated throughout the literature on human genetics. However, the accuracy of the original observations on which the concept is based has been questioned; therefore, data should be considered with great caution.

Mutation	Gene Symbol	Phenotypic Expression			
		XY	Heterozygotes XY	XX	Homozygotes XY XX
1 Interstitial nephritis		Severe, usually fatal.	Unknown	Mild or no disease observed	Unknown
2 Total color blindness	ac	←	Normal.	←	← Day blind. →
3 Xeroderma pigmentosa	xe	←	Freckled.	←	← X. pigmentosa. →
4 Oguchi's disease	og	←	Normal.	←	← Night blindness without myopia. →
5 Recessive epidermolysis bullosa	ep	←	Normal.	←	← Skin blisters with scarring. →
6 Dominant retinitis pigmentosa	Re	←	Pigmented retina with blindness.	←	← Unknown. →
7 Recessive retinitis pigmentosa	re	←	Normal.	←	← Pigmented retina with blindness. →
8 Recessive spastic paraplegia		←	Normal.	←	← Spasticity, exaggerated tendon. →

83. MUTATION RATES: MAN

Knowledge of mutation rates in man as in other organisms is still considered provisional, and the traits for which estimates are available are a highly selected fraction of all genes. Estimates for chondrodystrophy, aniridia and neurofibromatosis may be more reliable than those for epiloia and Waardenburg's syndrome. In some cases, significant figures have been reduced although two digits do not imply greater accuracy than one. Reported estimates for autosomal recessive traits are probably not reliable. The error in these estimates is unknown but may be appreciable.

Character	Method of Estimation ¹	Mutations per Gene in One Generation	Remarks
Dominant Genes			
1 Epiloia	Direct	$0.4-0.8 \times 10^{-5}$	
2 Chondrodystrophy	Direct	4.9×10^{-5}	Estimates may be spuriously high because of some evidence of phenocopies.
3	Direct	4.2×10^{-5}	
4	Direct	7×10^{-5}	
5	Indirect	4.3×10^{-5}	
6 Pelger's nuclear anomaly	Direct	2.7×10^{-5}	
7 Aniridia	Direct	0.5×10^{-5}	
8 Retinoblastoma	Direct	4.3×10^{-6}	Estimate based on proposition that 75% of all sporadic cases of retinoblastoma are phenocopies.
9 Retinoblastoma	Direct	1.4×10^{-5}	Estimates by treating all cases as caused by mutation.
10	Direct	2.3×10^{-5}	
11 Waardenburg's syndrome	Direct	3.7×10^{-6}	
12 Neurofibromatosis	Direct	$1.3-2.5 \times 10^{-4}$	
13	Indirect	$0.8-1.0 \times 10^{-4}$	
14 Facio-scapulo-humeral progressive muscular dystrophy	Direct	4.7×10^{-6}	
15	Indirect	4.7×10^{-6}	
16 Multiple polyposis of the colon	Indirect	$1.0-3.0 \times 10^{-5}$	
Sex-linked Recessive Genes			
17 Hemophilia	Indirect	3.2×10^{-5}	Estimate may include three types of hemophilia: (a) classical sex-linked hemophilia caused by a deficiency of anti-hemophilic globulin, (b) a sex-linked clotting defect caused by a lack of "plasma thromboplastin component," and (c) an autosomally inherited clotting defect caused by a lack of "plasma thromboplastin antecedent."
18 Childhood progressive muscular dystrophy	Direct ²	1×10^{-4}	
19	Indirect	1×10^{-4}	
20	Indirect	$4.5-6.5 \times 10^{-5}$	
21	Direct	3.2×10^{-5}	
22	Indirect	3.8×10^{-5}	

/1/ All indirect estimations make use of estimates of the relative fitness, and frequency at birth, of the trait, and assume that the population is in equilibrium. /2/ Not a true direct estimate but an approximation which overestimates the mutation rate.

84. LINKAGE GROUPS: VARIOUS ANIMALS

Size or length of linkage maps reflects the intensity of genetics investigation on an organism rather than the number of genes possessed by the organism. Symbols for genes are capitalized only when characterized by dominance. Numbers in brackets are footnote references.

Locus	Symbol	Mutation and Phenotype	Locus	Symbol	Mutation and Phenotype
Mouse, house (Mus musculus) [1]			Mouse, house (Mus musculus) [1] (concluded)		
Linkage Group I			Linkage Group XI		
1	16	fr Frizzle. Decreased proportion of coarser types of hair; vibrissae curled.	42	9	wa-1 Waved. Short whiskers, waved hair.
2	4, 3	sh-1 Shaker-1. Deaf; choreic head movements.	43	Wh	White. Snow-white fur; eyes pink, reduced in size.
3	16, 12	c[2] Albinism. Absence of pigmentation.	Linkage Group XII		
4		p Pink-eye. Pink eyes; reduction of black or brown pigment in coat.	44	je	Jerker. Deaf; resembles waltzing.
5		o Oligodactyly. Homozygotes lack 5th (or 4th and 5th) toe on front and/or hind feet.	45	ru	Ruby-eye. Eyes vary between ruby and pink.
Linkage Group II			Linkage Group XIII		
6	0.16	d Dilution. Clumping of pigment in coat color.	46	Lp[6]	Loop-tail. Twisted tail, wobbling head.
7		se Short ear. Reduction of pinna.	47	py	Polydactyly.
Linkage Group III			48	ln	Lead. Resembles maltese dilution (blue).
8	8	s Spotting. Unpigmented areas on fur.	49	Sp	Spotch. White spotting on belly, occasionally on back.
9	33	hr Hairless. Shedding of hair at 10-14 days.	50	fz	Fuzzy. Thin and faintly wavy hair.
10	7	pi Pirouette. Whirling movements, resembles waltzing.	Linkage Group XIV		
11	18	W Dominant spotting. Homozygous lethal.	51	28	cr Crinkled. Modified hair structure.
12	16	lx Hemimelia tibiae. Reduction of tibia generally associated with bent fibula.	52	15	f Flexed-tail. Causes anemia and belly-spot.
13		rl Reeler. Impaired locomotion through disturbed balance.	53	ch	Congenital hydrocephalus. Lethal at birth.
Linkage Group IV			Linkage Group XX (Sex Chromosome)		
14	12	r Rodless retina. Outer nuclear layer of retina rodless.	54	Bn	Bent-tail. Viability of homozygous females and bent-tail males much reduced.
15		si Silver. Absence or reduction of pigment granules.	55	Ta	Tabby. Coat of heterozygous females transversely striped. Homozygous females and tabby males with coat resembling crinkled (cr).
Linkage Group V			56	Br	Brindled. Coat flecked with patches of light hair.
16		Ra[3] Ragged. Affects coat texture.	57	0(?)	Brindled males die prior to 3 weeks.
17	3	kr Kreisler. Deaf, prolonged running in circles.	58	21	Mo Mottled. Similar to brindled except that males die in utero; perhaps an allele of Br.
18	5	a Non-agouti. Determines pigment distribution of black, brown and yellow in individual hair.	59	(?)	jp Jumpy. Behavior disorder manifest in hemizygous males at about 11 days and lethal at 25-32 days.
19	10	un Undulated. Tail undulations; sometimes hunchback; animals often runts.		To	Tortoise shell. Similar to mottled but probably not allelic. Position not determined.
20	3	we Wellhaairig. Shortened whiskers at birth, later curved.	Rabbit (Lepus cuniculus)		
21	19	pa Pallid. Pink eyes, agouti coat color.	Linkage Group I		
22	8	fi Fidget. Head shaking side to side, some circling.	60	0	c Albinism. Coat color alleles vary from chinchilla to complete albinism.
23	17	hy-1 Hydrocephalus-1. Dome-shaped, or increased head size from ventricular distension.	61	14.4	y Yellow fat.
24		Sd Danforth's short tail. Affects urogenital system. Homozygotes lethal. Heterozygotes short-tailed or tailless.	62	42.8	b Brown. Brown coat color.
Linkage Group VI			Linkage Group II		
25	11.6	bt Belted. Dorsal white spotting in belt area.	63	0	du Dutch pattern. White belt on colored background.
26		Ca Caracul. Hair lies in fluffy waves, straightens later. Whiskers curved.	64	1.2	En English. Colored spots on white background.
27	0, 3	N Naked. Hair breaks off at 10-14 days.	65	14.3	l Angora hair. Increased hair fiber length.
Linkage Group VII			Linkage Group III		
28	29	wa-2 Waved-2. Wavy coat.	66	0	r1 Rex-1. Short plush-like coat.
29	20	sh-2 Shaker-2. Deaf, choreic head movements, whirling in circles.	67	17.2	r2 Rex-2. Short plush-like coat.
30		Re Rex. Curly whiskers in juvenile. Curly vibrissal and short curly guard hairs.	Linkage Group IV		
31		vt Vestigial.	68	0	a Non-agouti. Coat color black.
32		Tr Trembler. Spastic paralysis in legs; more marked in hind pair.	69	14.7	dw Dwarf. Small size, lethal shortly after birth.
Linkage Group VIII			70	29.9	w Wide-banded agouti. Wide banding of agouti hairs.
33	7	[4] Brown. Coat color brownish hue.	Linkage Group V		
34		m Misty. Dilutes fur color, produces white tail tip in heterozygotes.	71	0	br Brachydactyly. Abnormality of toes.
35		an Anemia. Small, pale, sterile.	72	28.3	f Furless. Fur restricted to extremities.
Linkage Group IX			73	36.8	an Erythrocyte agglutinin.
36	4.3	T[5] Brachyury. Short tail. Homozygotes inviable.	Linkage Group VI		
37	2(?)	Ki Kinky tail. Possibly an allele of Fu. Homozygotes inviable.	74	0	E Extension. Extension of dark pigment.
38	3.9	Fu Fused. Resembles short tail. Expression variable.	75	26.2	At Production of atropinesterase.
39		H-2 Histocompatibility-2. Determines susceptibility and resistance to tissue transplants.	Guinea pig (Cavia porcellus) [1]		
Linkage Group X			Linkage Group I		
40	20	v Waltzing. Deaf, moves in circles.	76	42.4±	R Rough fur at least on hind toes.
41		ji Jittery. Muscular incoordination in righting after being placed on back.	77		Px Pollex. Tendency to return of thumb, little toe and rarely big toe.
			Linkage Group II		
			78	24.4±	si Silvered (stationary from birth). Incomplete recessive.
			79		m Modifier. Modifies rough fur effect. Homozygote high grade roughness.
			Rat, common (Rattus norvegicus) [7]		
			Linkage Group I		
			80	0	p Pink-eye. Coat yellow, eyes pink.
			81	20.5	r Red-eyed yellow. Coat yellow, eyes red.
			82	21	c Albino. Absence of pigment from coat and eyes.
			83	24.3	l Lethal. Skeleton imperfect.
			84	66.3	w Waltzing. Runs in circles.

/1/ Locus values for house mouse, guinea pig, fowl and parasitic wasp are recombination percentages between successive genes listed. Where two values appear, the first represents data from heterozygous females and the second from heterozygous males. /2/ c-o = 15, 20. /3/ Ra-a = 24. /4/ b-an = 7. /5/ T-Fu = 4.3. /6/ Lp-ln = 35. /7/ Jaundice (j), curly coat (Cu2), cataract (Ca), blue dilution of coat (d), hooded coat pattern (h), cowlick (cw), and shaker (sr) have been found to be independent of linkage groups I-V and of each other and are provisionally regarded as markers of seven additional chromosome pairs.

84. LINKAGE GROUPS: VARIOUS ANIMALS (Continued)

Size or length of linkage maps reflects the intensity of genetics investigation on an organism rather than the number of genes possessed by the organism. Symbols for genes are capitalized only when characterized by dominance. Numbers in brackets are footnote references.

Locus	Symbol	Mutation and Phenotype	Locus	Symbol	Mutation and Phenotype
Rat, common (<i>Rattus norvegicus</i>) [7] (concluded)			Silkworm (<i>Bombyx mori</i>) (concluded)		
Linkage Group II			Linkage Group VIII		
85	0	Shaggy. Hair and vibrissae curved.	128	0	Amylase negative. Amylase in digestive fluid weak.
86	4	Cu. Curly. Hairs of coat and vibrissae curved.	129	1.1	be. Amylase negative. Amylase in body fluid (hemolymph) weak.
87	14.3	an. Anemia. Lack of red blood cells. Young anemic.	Linkage Group IX		
88	28	in. Incisorless. Incisors lacking.	130	0	I. Yellow inhibitor. Suppression of yellow blood and yellow cocoon.
89	47	s. Silvered coat.	131	5.9	I-a. Dominant chocolate. Like chocolate, head black.
90	52	b. Brown. Chocolate pigmentation.	132	6.7	bd. Dilute black. Whole larval body dilute black.
Linkage Group III			133	7.4	og. Giallo Ascoli. High degree translucency. Female almost sterile.
91	0	n. Naked, except for short fuzzy coat.	Linkage Group X		
92	45	hr. Hairless. Hair lost at about 4 weeks of age.	134	0	w ₁ (w-1). White egg 1. No pigment in serosa, white eyes in moth.
93	88	wo. Wobbly. Ataxic locomotion.	135	0.0+	fl. Wingless. Fore and hind wings absent in pupa and moth.
Linkage Group IV			136	3.4	w ₂ (w-2). White egg 2. Egg gradually changes from white to light reddish color. White eyes in moth.
94	0	k. Kinky. Hairs of coat and vibrissae kinky.	137	6.9	w ₃ (w-3). White egg 3. Light purplish-brown egg. Black eyes in moth.
95	34.1	st. Stub. Short stubby tail.	Linkage Group XI		
Linkage Group V			138	0	K. Knobbed. Dermal protuberances appear on dorsal sides of several segments of larva, pupa and moth.
96	0	A. Agouti. Fur color wild type, agouti.	139	5.5	Bu. Burnt. Larva skin from 2nd to 5th segments shows burn-like scar.
97	44.6	f. Fawn. Tawny blue to fawn coat color.	140	17.1	bp. Black pupa.
Silkworm (<i>Bombyx mori</i>)			141	24.0	mp. Micropterous. Small wings.
Linkage Group I (Z Chromosome)			Linkage Group XII		
98	0	os. Low degree of translucency of larva.	142	0	Ng. No glue. Eggs easily separated from papers because of poor development of mucous glands in females.
99	14	Ge. Giant egg. Length and width 1.26 and 1.11, respectively, times the normal egg.	143	14.0	C. Golden egg. Cocoon golden yellow outside, nearly white inside.
100	36.4	e. Elongate. First and second abdominal segments of larva unusually elongated.	144	52.1	rd. Clumpy. Irregular egg shape and highly variable.
101	38.7	Vg. Vestigial. Wings poorly developed.	Linkage Group XIII		
102	49.6	od. Translucent. Skin of larva shows high degree of translucency.	145	0	ch. Chocolate. Newly hatched larva reddish-brown.
Linkage Group II			146	11.3	cf. Crayfish. Fore and hind wings swollen and protrude laterally from body in pupa.
103	0	P. Plain. Full grown larva white. +p, p ^B , p ^M , p ^S , p ^{SA} multiple or pseudo-alleles of p.	Linkage Group XIV		
104	6.1	S. New striped. Dark stripe on larva. Heterozygote almost as dark as homozygote.	147	0	Di. Dirty. Irregular black lines and dots cover dorsal surface of larva.
105	6.9	Gr. Gray egg. Milky white shell, dark serosa pigment.	148	2.7	U. Ursa. Dark brown pigments cover dorsal and lateral sides of larva.
106	25.6	Y. Yellow blood. Deep yellow hemolymph in larva.	149	10.7	odk. Mottled. Low degree translucency.
107	26.7	oa. Mottled translucent. Mottled translucency on larval skin.	Linkage Group XV		
108	31.8	Rc. Rusty. Yellowish-brown cocoon, lighter inner layer.	150	0	Se. White side egg. Egg surface irregular and with many furrows.
Linkage Group III			151	7, 8	Gc. Green c. Green cocoon.
109	0	Ze. Zebra. Black band on anterior end of each segment. Pair of black spots on ventral side of each larval segment.	Parasitic wasp (<i>Habrobracon juglandis</i>) [1]		
110	0	ap. Apodal. All thoracic legs rudimentary.	Linkage Group I		
111	22.8	lem. Lemon. Greenish-yellow coloring over skin visible from second instar.	152	12	Sk. Speckled. Bright red flecks of pigment in white eye.
Linkage Group IV			153	13	r. Reduced. Small wings. Reduced, irregular venation.
112	0	L. Multilunar. Pairs of large brownish or yellowish round spots on thoracic and abdominal segments.	154	30	gl. Glass. Small eyes, lacks facet outlines.
113	25.8	sk. Stick. Larva body slender and hard.	155	10	x. Sex gene. Nine factors known. Determine sex differences.
114	33.1	Spc. Speckle. Many dark spots on larval skin. Female sterile.	156	22	fu. Fused. Antennal segments fused. Tarsal segments lacking or fused.
Linkage Group V			157	42	sb. Stubby. Males with antennae 7-9 segments long. Females with antennae 5-7 segments long.
115	0	pe. Pink-eyed. White egg. Pigment absent from serosa.	158	30	bl. Black. Body color.
116	4.7	ok. Kinshiryu. High degree translucency of larva.	159	12	le. Lemon. Body color pale lemon-yellow.
117	31.7	re. Red egg. Reddish-brown serosa.	160	14	c. Cantaloup. Eyes light pink, darken to deep red.
118	40.8	oc. Chinese. High degree translucency of larva.	161	3	l. Long. Antennal segments elongated. Leg segments longer and thinner than wild type.
Linkage Group VI			162	7	n. Narrow. Narrow wings, cuts off irregular slices of costal and inner wing margins.
119	0	E. Plain supernumerary legs. Supernumerary legs in 1st and 2nd abdominal segments of larva. E _{Ca} , E _D , E _H , E _{Kp} , E _N multiple of pseudo-alleles of E.	163	8	ho. Honey. Body lacks black pigment entirely.
120	1.4	Nc. No crescent supernumerary legs. Supernumerary leg in the 2nd abdominal segment.	164	15	vl. Veinless. Wing veins missing, except along costal margin.
121	3.0	+M. Tetra molting. Standard type, larva pupates after 4th molt. M ³ , M ⁵ multiple or pseudoalleles of +M.	165	12	ro. Rough. Fourth radius vein absent and adjacent veins roughened.
122	8	b ₂ . Brown egg 2. Grayish-brown pigment in serosa.	166	37	bu. Bulged. Eyes abnormally bulged transversely.
123	13.6	F. Flesh. Cocoon color reddish-yellow or salmon.	167	41	cr. Crescent. Eyes small. Pigment in ocelli reduced, crescent-shaped.
124	17.7	l-k. Lethal-k. Embryo killed few days before hatching.	168		al/co. Semilong. Antennal and leg segments lengthened.
Linkage Group VII					
125	0	q. Quail. Larval body tinted reddish-purple and covered with shreddlike lines.			
126	7.0	Gb. Green b. Greenish cocoon color.			
127	21	obt. B ₈ -mottled. Moderate degree translucency of larva. Not lethal.			

/1/ Locus values for house mouse, guinea pig, fowl and parasitic wasp are recombination percentages between successive genes listed. Where two values appear, the first represents data from heterozygous females and the second from heterozygous males. /7/ Jaundice (j), curly coat (Cu₂), cataract (Ca), blue dilution of coat (d), hooded coat pattern (h), cowlick (cw), and shaker (sr) have been found to be independent of linkage groups I-V and of each other and are provisionally regarded as markers of seven additional chromosome pairs.

84. LINKAGE GROUPS: VARIOUS ANIMALS (Continued)

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Locus			Symbol	Mutation and Phenotype	Locus			Symbol	Mutation and Phenotype
Parasitic wasp (<i>Habrobracon juglandis</i>) [1] (concluded)					Domestic fowl (<i>Gallus gallus</i>) [1] (concluded)				
Linkage Group I (concluded)					Linkage Group V				
169	33	sl/co	Coalescent. Antennal segments coalescent.	219	43	Na	Naked neck. Pterygiae reduced.		
170	32	ct	Cut. Outer wing margin indented or straightened, giving cut appearance.	220	11	h	Silkie. Barbules lack hooklets.		
171	37	rd	Red. Color varies from light red to dark red or almost black with temperature.	221		F1	Flightless. Remiges break off.		
172	7	gy	Gynoid. Short antennae in male, resembling female. Abdominal sclerites resemble female.	Linkage Group VI					
173		ac/el	Aciform. Terminal half of antennae very slender, needle-like.	222	26	D	Duplex comb. Bifurcation of comb.		
174			Eyeless. Heads malformed. Eye rudiments present.	223	33	M	Multiple spurs.		
Linkage Group II					224		Po	Polydatyly.	
175	28	k	Kidney. Kidney eye shape.	Fruit fly (<i>Drosophila melanogaster</i>)					
176	5	dw	Dwindling. Irregularity and fusion of antennal segments.	X Chromosome (Element A)					
177	11	m	Miniature. Reduced body size. Semi-lethal, may die as pupa.	225	0	1(1)J1	Lethal (1) Jacobs-Muller. Almost complete lethal.		
178		o	Orange. Eyes orange varying to pink and red.	226	0	y	Yellow. Body yellow, bristles and larval mouth parts brown.		
Linkage Group III					227	0+	ac	Achaete. Postdorsal centrals missing, fewer intra-ocellar hairs.	
179	25	bk	Broken. Outer margin of primary wing broken and wings fragile.	228	0+	Hw	Hairy-wing. Extra bristles and hairs along wing veins.		
180		wh/pl	White. White eye. Ocelli colorless.	229	0+	sc	Scute. Scutellars missing and other bristles fewer.		
181	9		Pellucid. Compound eyes semi-transparent.	230	0+	avr	Silver. Body, legs pale, bristles dark.		
182		st	Stumpy. Extreme reduction of tarsal segments.	231	0+	su-s	Suppressor of sable.		
Linkage Group IV					232	0+	1(1)7e	Lethal (1)7e. Kills 1(1)7 early.	
183	23	sv	Shot-veins. Wing veins broken and distorted	233	0+	saw	Sawtooth. Serrated hair along wing edges.		
184	27	td	Truncated. Wings extremely reduced, irregular in shape, (not truncate, tr).	234	0.1	su-b	Suppressor of black.		
185		ma	Maroon. Light ocelli. Compound eyes deep reddish brown.	235	0.1+	om	Ommatidia. Eyes slightly rough.		
Linkage Group V					236	0.1+	M(1)Bld	Minute (1) blond. Extreme Minute. Deficiency.	
186	22	wa	Wavy. Wings shortened. Costal margin wavy.	237	0.3	1(1)7	Lethal (1)7. Melanotic tumors in larva; lethal.		
187		br	Broad. Thorax abnormally broadened.	238	0.3+	sta	Stubarista. Aristae stubby, bristles short.		
Linkage Group VI					239	0.4+	tw	Twisted. Abdomen twisted counterclockwise.	
188	40	ta	Tapering. Antennae deficient with much fusion and irregularity of segments distally.	240	0.6	br	Broad. Wings broad, short.		
189		un ²	Undulating-2. Surface of wings in undulating waves.	241	0.7	kz	Kurz. Bristles short, slender.		
Linkage Group VII					242	0.7+	rey	Rough eye. Small rough eye.	
190		pk/ew ³	Pink. Compound eyes pink.	243	0.8	pn	Prune. Eye color dark brownish red, often mottled.		
191			Extended wings. Wings extended in active wasps.	244	0.9	gt	Giant. Giant larvae, pupae, flies.		
Linkage Group VIII					245	1.5	w	White. White eyes, testes, larval Malpighian tubules.	
192	18	wt	Wet. Wing microchaetae very long and irregular giving wet appearance.	246	1.7	rst	Roughest. Eyes large, very rough.		
193		bf	Black feet. Tarsi abnormally black.	247	3+	Co	Confluens. Veins thick, deltoid.		
Domestic fowl (<i>Gallus gallus</i>) [1]					248	3+	spl	Split. Eyes rough, small. Bristles split.	
Linkage Group I (Sex Chromosome)					249	3+	fa	Facet. Eyes rough, wings nicked.	
194	13	ko	Head streak in down.	250	3+	Ax	Abruptex. Wings arched, veins short.		
195	10	B	Barring.	251	3	N	Notch.		
196	27	Id	Inhibitor. Inhibits melanin in dermis.	252	4.6	dm	Diminutive. Body, bristles small.		
197	10	br	Brown eyes.	253	5+	M(1)3E	Minute (1) at 3E. Slight Minute.		
198	16	Li	Light down. In chicks not black.	254	5+	suX-dx	Suppressor of dextex.		
199	11	S	Silver. Plumage color.	255	5.5	ec	Echinus. Eyes and facets large, rough.		
200		K	Slow feathering.	256	6.9	bi	Bifid. Veins fused at wing base.		
201		sd	Dilution to blue.	257	7+	M(1)4BC	Minute (1) at 4BC. Strong Minute.		
202		n	Naked.	258	7.3+	peb	Pebbled. Eyes slightly rough.		
203		al	Albinism. Incomplete.	259	7.5	rb	Ruby. Eye color clear ruby.		
204		dw	Dwarf.	260	8	dow	Downy. Bristles fuzzy. Female sterile.		
205		xl	Lethal, after three weeks.	261	11	rg	Rugose. Wings thin, frayed.		
206		sh	Shaker. Lethal nervous disorder.	262	12.5	bo	Bordeaux. Eye color wine.		
207		j	Jittery. Lethal nervous disorder.	263	13.6	cx	Curlex. Wings curled upward.		
Linkage Group II					264	13.7	cv	Crossveinless. Crossveins absent or traces.	
208	0.4	Cp	Creeper. Achondroplasia.	265	15	rux	Roughex. Eyes small, rough. Male sterile.		
209	30	R	Rose comb.	266	15.2+	Ext	Extras. Veins augmented. Lethal in male.		
210		U	Uropygial. Bifurcation of uropygial papilla.	267	16.3	vs	Vesiculated. Wings warped, inflated, divergent.		
Linkage Group III					268	17	dx	Deltex. Veins thickened, delta-like.	
211	46	fr	Fray. Defective wing and tail feathers.	269	17.5	ov	Oval. Eyes oval rough.		
212	12.5	Cr	Crest. Top-knot and cerebral hernia.	270	17.9	shf	Shifted. Vein L3 fails to reach wing margin.		
213		I	Dominant white. Plumage.	271	18.9	cm	Carmine. Eye color dark ruby.		
214	17	F	Frizzling. Recurved feathers.	272	19.3	scp	Scooped. Wings upturned, warped.		
Linkage Group IV					273	20	ct	Cut. Wing scalloped at edges.	
215	5	O	Blue eggshell color.	274	21	sn	Singed. Bristles and hairs curled. Female sterile.		
216	33	P	Pea comb.	275	23.1	oc	Ocelliless. Ocelli absent. Female sterile.		
217	46	ma	Marbling. Pattern in down of chick.	276	23.1+	gg	Goggle. Eyes bulging, head bristles fewer.		
218		Na	Naked neck. Pterygiae reduced.	277	23.2	ptg	Pentagon. Dark trident and thoracic spot.		
				278	23.8	ch-b	Chilblained-b. Tarsi conglutinated.		
				279	24.3	dd	Displaced. Antennae and eyes deformed.		
				280	25+	tbd	Tiny-bristleoid. Bristles Minute type.		
				281	27.1+	con	Condensed. Body, wings short, eyes rough.		
				282	27.5	t	Tan. Body and antennae yellowish.		
				283	27.7	amx	Almondex. Eyes reduced, narrow. Female sterile.		
				284	27.7+	lz	Lozenge. Eyes narrow, ovoid. Female usually sterile.		
				285	28.1	dvr	Divers. With y, wings strongly curled.		
				286	31+	flp	Flap wings. Wings concave, eyes slightly rough.		

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Locus	Symbol	Mutation and Phenotype	Locus	Symbol	Mutation and Phenotype
Fruit fly (<i>Drosophila melanogaster</i>) (continued)			Fruit fly (<i>Drosophila melanogaster</i>) (continued)		
X Chromosome (Element A) (concluded)			Chromosome II (Elements B and C) (continued)		
287	32a	ny Notchy. Wing tips nicked.	357	16.5	cl Clot. Eye color maroon, close to sepia.
288	32.8	ras Raspberry. Eye color dark ruby.	358	17a	pi Pied. Facets jumbled.
289	33	v Vermilion. Eye color bright vermilion, ocelli colorless.	359	22	Sp Sternopleural. Extra sternopleural bristles. Homozygous lethal.
290	33.2	dwx Dwarfex. Body small, wings coarse.	360	22.3a	spd Spade. Wings shortened. broad.
291	33.4	sbr Small bristle. Bristles small, some missing.	361	24	gt-4 Giant-4. Giant flies.
292	36.1	m Miniature. Wings small, dark.	362	31	d Dachs. Tarsi 4-jointed, venation shifted.
293	36.2	dy Dusky. Wings small, dusky.	363	33a	fy Fuzzy. Thoracic hairs fuzzy.
294	36.4	ty-l Tiny-like. Bristles short, fine.	364	39a	fol Folded wings.
295	38.3	fw Furrowed. Eyes furrowed, scutellum shortened, bristles gnarled.	365	39.3a	da Daughterless. Homozygous females produce no daughters.
296	41.9	wy Wavy. Wings waved, curled.	366	41	J Jammed. Wing narrow strip.
297	42a	kk Kinky. Bristles bent or forked.	367	43a	M(2)S11 Minute(2)Schultz'11. Slight Minute.
298	43	s Sable. Body black.	368	44	ab Abrupt. Shortened L5 vein, scutellars few.
299	44.4	g Garnet. Eye color garnet pink.	369	45a	oph Ophthalmopodia. Eyes kidney-shaped or with appendage.
300	44.5	ty Tiny. Bristles, body small. Female sterile.	370	46a	rk Rickets. Segments of legs flattened and bent.
301	45.2	na Narrow abdomen. Abdomen cylindrical. Female sterile.	371	46a	1(2)bs ³ -d Lethal(2) with bs ³ -d. Lethal.
302	47.9	pl Pleated. Wings pleated.	372	46a	M(2)e Minute(2)e. Medium Minute.
303	49.3a	vb Vibrissae. Vibrissae in tuft.	373	48.5	b Black. Body, legs, veins black.
304	51.5	sd Scalloped. Wing margins excised.	374	48.7	j Jaunty. Wings upturned.
305	51.6	Bg Bag. Wings short, blunt, inflated.	375	50	el Elbow. Wings bent, alulae and balancers small.
306	53.5	sl Small-wing. Wings short, oblong. Eyes large.	376	50a	lm Limited. Sternites small. Female sterile.
307	54	mc Microchaete. Hairs, bristles few and small.	377	50a	M(2)S13 Minute(2)Schultz'13. Strong Minute.
308	54.4	un Uneven. Eyes rough, small.	378	50a	1(2)H Lethal(2)Humphrey. Pupal semilethal.
309	54.5	r Rudimentary. Wings short, oblique. Female sterile.	379	50.5	Su-H Suppressor of hairless. Homozygous lethal.
310	55a	if Inflated. Wings inflated, veins thickened.	380	51	rd Reduced. Bristles small, irregular. Female sterile.
311	56a	cs Creased. Wings longitudinally creased.	381	51a	pu Pupal. Wings unexpanded.
312	56.6	M(1)o Minute(1)o. Minute type.	382	52a	pys Polychaetous. Extra and double bristles.
313	56.7	f Forked. Bristles, hairs gnarled.	383	52.5a	cr-u Cream-underscored. Specific dilutor of w ^e and Pale. Male sterile.
314	57	B Bar. Eyes narrow.	384	53	nub Nubbin. Wings very small and thin with tendency to curve up or down.
315	59.2	od Outstretched. Wings divergent.	385	53a	ck Crinkled. Wings flimsy.
316	59.2	ay Small-eye. Eyes small, rounded.	386	53a	rdo Reduced ocelli. Ocelli reduced in size, color moved to region between ocelli.
317	59.4	Bx Beadex. Wings excised.	387	53.1	1(2)Bld Lethal(2) opposite T(1;2)Bld. Lethal.
318	59.5	fu Fused. Wing veins fused at base.	388	53.5	M(2)S5 Minute(2)Schultz'5. Medium Minute.
319	62a	M(1)36f Minute(1)36f. Slight Minute.	389	53.9	hk Hook. Bristles bent or barbed.
320	62.5	car Carnation. Eye color dark ruby.	390	54.3a	bri Bright. Eye color bright red.
321	62.7	M(1)n Minute(1)n. Extreme Minute.	391	54.5	pr Purple. Eye color purplish ruby.
322	63a	fo Folded. Wings unexpanded.	392	54.5a	rn Rotund. Wings round, tarsi 3-jointed. Sterile.
323	64	aw Short-wing. Wings trimmed, eyes small, rough.	393	54.7a	rh Roughish. Eyes moderately rough.
324	64a	su-f Suppressor of forked.	394	54.8	Bl Bristle. Bristles short, beaded. Homozygous semi-lethal.
325	65.6	cf Cleft. Wing venation increased.	395	54.9	Alu Alula. Alula fused to wing. Wing warped.
326	66	bb Bobbed. Bristles small, sclerites irregular.	396	54.9	Jag Jagged. Wings nicked, eyes rough.
Chromosome II (Elements B and C)			397	55	lt Light. Eye color yellowish pink.
327	0	net Net. Extreme plexus venation.	398	55a	tri Trident. Thorax darkened.
328	0	al Aristalless. Aristae reduced, scutellars divergent.	399	55a	M(2)D Minute(2)D. Body color and bristles pale.
329	0a	1(2)gl Lethal(2) giant larva. Larval lethal.	400	55.1-	r1 Rolled. Wing edges rolled, frayed.
330	0	ocr Ochracea. Eye color light, darkening with age.	401	55.1	M(2)S2 Minute(2)Schultz'2. Minute type. Deficiency.
331	0.1	ex Expanded. Wings broad, spread. Eyes rough.	402	55.1	M(2)S4 Medium Minute. Deficiency.
332	0.3	ds Dachsous. Wings shorter, crossveins closer.	403	55.1	M(2)S8 Slight Minute. Deficiency.
333	1.3	S Star. Eyes small, rough. Homozygous lethal.	404	55.1	M(2)S10 Minute(2)Schultz'10. Slight Minute. Deficiency.
334	1.3a	Su-S Suppressor of Star.	405	55.1	stw Straw. Body, wings, bristles yellow.
335	1.3a	ast Asteroid. Eyes small, rough.	406	55.2a	blt Blot. Wings inflated, blackened.
336	2.3a	shr Shrunk. Body small, wizened.	407	55.2a	Cu Curl. Lateral compression and indentation-fold of unfolded imaginal wing.
337	3.8a	shv Short vein. Constant terminal gaps in veins L2 and L4.	408	55.3	tk Thick. Legs, tarsi, thickened, wings short.
338	4	ho Heldout. Wings extended.	409	55.3	pk Prickle. Bristles, hairs irregular.
339	5a	fes Female-sterile. Eggs do not develop.	410	55.4	ap Apterous. Wings, balancers missing.
340	6a	E-S Enhancer of Star. Increases expression of Star.	411	55.6-	msf Misformed. Eyes misformed, wings crumpled.
341	7	Cy Curly. Wings curled upward. Homozygous lethal.	412	55.7a	bur Burgundy. Dull, darkish-brown eye color.
342	8.3	1(2)ay Lethal(2)ay. Lethal.	413	55.9	ti Tarsi irregular. Tarsal segments fused, eyes rough.
343	10a	Dt Detached. Vein L2 does not reach margin.	414	56a	ltd Lightoid. Eye color clear, translucent yellowish pink. Ocelli colorless.
344	10.5	ang Angle wing. Wings held up from dorsal surface.	415	56a	M(2)S12 Minute(2)Schultz'12. Slight Minute.
345	11	ed Echinoid. Eyes large, rough.	416	56.5a	std Staroid. Eyes small, very rough.
346	11-12	M(2)C Minute(2) Curry. Fairly strong Minute. Deficiency.	417	56.6a	ta Tapered. Wings narrow and pointed. Veins close. Male sterile.
347	12	ft Fat. Body short, fat. Scutellar bristles far apart.	418	57a	dil Specific dilutor. Dilutor of bw and w alleles.
348	12	G Gull. Wings large, spread. Homozygous lethal.	419	57.1	buo Burnt orange. Eye color orange-brown.
349	12.9a	M(2)z Minute(2)z. Medium Minute.	420	57a	M(2)38b Minute(2)38b. Extreme Minute.
350	13	M(2)B Minute(2) Bridges. Medium Minute. Deficiency.	421	57.5	cn Cinnabar. Eye color bright scarlet. Ocelli colorless.
351	13	dp Dumpy. Wings truncated. Vortices on thorax.	422	58a	puf Puff. Wings blistered.
352	13a	dw-24F Dwarf in 24F. Eyes dull, body dwarf.	423	58.5	blo Bloated. Wings ballooned, extra veins.
353	15	M(2)S1 Minute(2)Schultz'1. Strong Minute.			
354	15a	1(2)cg Lethal(2)comb-gap. Lethal from cg stock.			
355	16	Sk Streak. Central streak on thorax. Homozygous lethal.			
356	16a	tkv Thick-veins. Veins thick, irregular.			

84. LINKAGE GROUPS: VARIOUS ANIMALS (Continued)

Size or length of linkage maps reflects the intensity of genetics investigation on an organism rather than the number of genes possessed by the organism. Symbols for genes are capitalized only when characterized by dominance. Numbers in brackets are footnote references.

Locus	Symbol	Mutation and Phenotype	Locus	Symbol	Mutation and Phenotype
Fruit fly (<i>Drosophila melanogaster</i>) (continued)			Fruit fly (<i>Drosophila melanogaster</i>) (continued)		
Chromosome II (Elements B and C) (continued)			Chromosome II (Elements B and C) (concluded)		
424	58.6± sm	Smoky. Body color dark.	485	107.2 or	Orange. Bright orange eye color.
425	58.7-60.2 Np	Notopleural. Bristles short, wings broad. Homozygous lethal. Deficiency.	486	107-107.4 Px	Plexate. Venation like bs. Veins thickened, broken. Homozygous lethal. Deficiency.
426	60.1± at	Arctus oculus. Number of facets reduced.	487	107.3 bs	Blistered. Wings blistered, small. Extra veins.
427	60.5± arch	Arch. Wings downcurved in both axes.	488	107.3± Pin	Pin. Thoracic bristles pin-like.
428	60.7 ad	Arcoid. Wings arched, broad, short. Cross-veins close.	489	107.4 ba	Balloon. Wings inflated, extra veins.
429	60.8 chl	Chaetelle. Bristles very small. Slight plexus.	490	108± M(2)33a	Minute(2)33a. Strong Minute. Deficiency.
430	61± whd	Withered. Wings warped or shrunken.	Chromosome III (Elements D and E)		
431	61.5± tom	Tomboy. Homozygous females with male-like pigmentation of posterior tergites.	491	0 ru	Roughoid. Eyes small, rough. Erupted facets.
432	62 en	Engrailed. Scutellar notch, broken veins, extra sex comb.	492	0 mp	Microptera. Wings small, ballooned. Tarsi 4-jointed.
433	62± upw	Upward. Wings upturned.	493	0± aa	Anarista. Aristae small, without branches.
434	63± l(2)rn	Lethal(2) with rotund. Lethal.	494	0.2 ve	Veinlet. Longitudinal wing veins interrupted.
435	65± Bkd	Blackoid. Dark body color.	495	1.4 R	Roughened. Eyes rough. Homozygous semilethal.
436	65± M(2)40c	Minute(2)40c. Minute type.	496	17± rai	Raisin. Deep brown eye color.
437	65.2 po	Pale-ocelli. Ocelli nearly colorless.	497	19.2 jv	Javelin. Bristles and hairs cylindrical.
438	66.7 sca	Scabrous. Eyes rough, some bristles missing.	498	20 dv	Divergent. Wings spread.
439	67 vg	Vestigial. Wings, balancers vestigial.	499	20± Me	Moire. Eye color brownish, 7 flecks. Homozygous lethal.
440	67 l(2)C	Lethal(2) Curry. Lethal before pupal stage.	500	23 Hn	Henna. Eye color dull, dark. Homozygous lethal.
441	69.7 wx	Waxy. Wings heavy, waxy. Male sterile.	501	25± be-3	Benign tumor in 3. Non-lethal melanotic tumors.
442	70± UH20	Upturned UH20. Wings curled.	502	26 se	Sepia. Eye color brownish red, darkening to black.
443	70± l(2)mr2	Lethal(2) with morula ² . Lethal.	503	26± su-t	Suppressor of tan.
444	70.8 Pfd	Pufdi. Wings puffed, divergent. Homozygous lethal.	504	26.5 h	Hairy. Extra hairs on scutellars, veins, pleurae, head.
445	71 bat	Bat. Wings extended, bent back.	505	27± abd	Abdominal. Abdominal bands broken, etched.
446	71.1 cg	Comb-gap. Sex combs large. Gap in wing vein L4. Female sterile.	506	35 rs	Rose. Eye color translucent pink.
447	71.2± dr	Droopy. Wings spread wide apart and drooping.	507	35.5 eyg	Eye-gone. Eyes and head reduced.
448	71.5± sf	Safranin. Eye color dark chocolate.	508	36.2 gv	Grooved. Longitudinal medial groove in thorax.
449	72 L	Lobe. Eyes small, nicked at anterior edge.	509	36.5± cr-3	Cream in 3. Specific dilutor of w ⁶ eye color.
450	72.3 kn	Knot. Veins L3 and L4 close. Eyes oblique.	510	37± rt	Rotated. Abdomen twisted counterclockwise.
451	72.5 ch	Chubby. Larva, pupa, adult short.	511	37.5 app	Approximated. Crossveins close. Tarsi 4-jointed.
452	73± dke	Dark eye. Eye color soft, dark, dull, with tiny fleck.	512	39± pyd	Polychaetoid. Extra bristles.
453	74± gp	Gap. Vein L4 broken.	513	39.7± M(3)S37	Minute(3)Schultz'37. Extreme Minute.
454	75.5 c	Curved. Wings thin, spread, lifted, curved.	514	40 tt	Tilt. Wings spread, warped, with gap in L3.
455	76± Wr	Wrinkled. Wings wrinkled. Suppresses Lobe.	515	40.2 M(3)33j	Minute(3)33j. Medium Minute. Deficiency.
456	77.5 M(2)S7	Minute(2)Schultz'7. Strong Minute.	516	40.2 M(3)h	Minute(3)h. Medium Minute. Allele of M(3)33j.
457	79± pw-c	Pink-wing-c. Eye color dilute, wings short, blunt.	517	40.2 M(3)y	Minute(3)y. Medium Minute. Allele of M(3)33j.
458	80± fr	Fringed. Wing margins ragged.	518	40.4± vo-3	Vortex in 3. Intensifier of dp ^v .
459	81± fj	Four-jointed. Tarsi 4-jointed. Wings short.	519	40.4± D	Dichaete. Wings spread. Homozygous lethal.
460	81± rf	Roof wings. Wings drooped at sides.	520	40.5 Ly	Lyra. Wings cut, narrow. Homozygous lethal.
461	82± wt	Welt. Eyes seamed, reduced.	521	41.4 Gl	Glued. Eyes small, facets rounded. Homozygous lethal.
462	83± abr	Abero. Abdominal bands irregular. Wings frayed, eyes rough. Female sterile.	522	41.7± fz	Frizzled. Thoracic hairs, bristles turn toward mid-line.
463	83± nw	Narrow. Wings narrow.	523	41.7± rp	Rotated-penis. Male genitalia rotated. Male sterile.
464	86.5 I-f	Intensifier or forked.	524	42± wk	Weak. Bristles weak, irregular. Body small.
465	91.5 sm	Smooth. Abdomen hairless.	525	43 Wi	Washed eye. Modifies w. Homozygous lethal.
466	92.3 M(2)173	Minute(2)173. Moderate Minute.	526	43.2 th	Thread. Aristae threadlike, without branches.
467	93.3 hy	Humpy. Thorax ridged, wings truncated.	527	43.4± mb	Minusbar. Modifies B to larger eye.
468	99± l(2)Su-H	Lethal(2) from suppressor of hairless. Lethal.	528	43.5± Cm	Crimp. Posterior wing edge crimped. Homozygous lethal.
469	99.2 a	Arc. Wings broad, bent down, crossveins closer.	529	43.6 bul	Bulge. Eyes bulging, wings squared off.
470	99-101.2 M(2)1	Minute(2)1. Extreme Minute. Deficiency.	530	44± M(3)S38	Minute(3)Schultz'38. Strong Minute.
471	100.5 px	Plexus. Network of extra veins.	531	44 st	Scarlet. Eye color scarlet, ocelli white.
472	101± pa	Patulous. Wings spread wide apart.	532	45± tra	Transformed. Transforms females to normal-appearing males.
473	101.2 M(2)1 ²	Minute(2)1 ² . Slight Minute.	533	45.3 cp	Clipped. Wing margins clipped.
474	104 hv	Heavy vein. Veins thick, posterior crossveins oblique.	534	46 mot-28	Mottled-28. Eyes mottled with brown.
475	104± l(2)bw	Lethal(2)brown. Probable deficiency. Lethal.	535	46 W	Wrinkled. Wings incompletely unfolded, pebbled.
476	104.5 bw	Brown. Eye color brownish to garnet.	536	46± as	Ascute. Wings held downward.
477	104.7 mi	Minus. Bristles hairlike. Body small.	537	46± je	Jelly. Eye color dark pinkish.
478	105.5 abb	Abbreviated. Bristles slightly reduced. Female sterile.	538	46± Pdr	Purpleoider. Intensifier of pd.
479	106.3 slt	Slight. Body small, bristles reduced.	539	47 in	Inturned. Thoracic bristles directed toward mid-line.
480	106.4 pd	Purpleoid. Eye color dark pink, like purple.	540	47± M(3)S39	Minute(3)Schultz'39. Strong Minute.
481	106.7± 11	Lanceolate. Wings narrow, pointed.	541	47± dn	Doughnut. Eye of se dn with light central spot. Male sterile.
482	106.7 mr	Morula. Eyes rough, bristles small.	542	47.1 ri	Radius incompletus. Vein L2 shows gap.
483	106.9 l(2)ax	Lethal(2)ax. Very early larval lethal.	543	47.3 eg	Eagle. Wings spread, raised.
484	107 sp	Speck. Black speck in wing axil. Body color olive.	544	47.5 Dfd	Deformed. Eyes small. Homozygous lethal.
			545	47.5 wp	Warped. Wings spread, doubly warped.

84. LINKAGE GROUPS: VARIOUS ANIMALS (Concluded)

Size or length of linkage maps reflects the intensity of genetics investigation on an organism rather than the number of genes possessed by the organism. Symbols for genes are capitalized only when characterized by dominance. Numbers in brackets are footnote references.

Locus	Symbol	Mutation and Phenotype	Locus	Symbol	Mutation and Phenotype
Fruit fly (<i>Drosophila melanogaster</i>) (continued)			Fruit fly (<i>Drosophila melanogaster</i>) (concluded)		
Chromosome III (Elements D and E) (continued)			Chromosome III (Elements D and E) (concluded)		
546	47.7 pb	Proboscipedia. Mouth parts footlike. Adult lethal.	586	79.7 M(3)124	Minute(3)124. Strong Minute. Allele of M(3)w.
547	48 p	Pink. Eye color dull ruby.	587	79.7 M(3)B	Minute(3)Burkart. Moderate Minute. Allele of M(3)w.
548	48± Bb	Bubble. Wings small, inflated. Male sterile. Homozygous female lethal.	588	79.7 M(3)B ²	Minute(3)Bridges. Strong Minute. Allele of M(3)w.
549	48.3 bod	Bowed. Wings arched.	589	79.7 M(3)w	Minute(3)w. Strong Minute.
550	48.5 tet	Tetraltera. Wings haltere-like.	590	79.7 1(3)a	Lethal(3)first found. Lethal. Allele of M(3)w.
551	48.7 by	Blistery. Wings blistered distally.	591	80± M(3)Fla	Minute(3)Florida. Strong Minute. Allele of M(3)w.
552	49± M(3)S34	Minute(3)Schultz'34. Slight Minute.	592	84.5 M(3)36e	Minute(3)36e. Medium Minute.
553	49.7 ma	Maroon. Eye color dull ruby.	593	87± M(3)be	Minute(3)beta. Medium Minute.
554	50 cu	Curled. Wings upcurved, body dark, post-scutellars crossed.	594	88± mah	Mahogany. Eye color brownish, darkening.
555	50 M(3)S31	Minute(3)Schultz'31. Medium Minute. Deficiency.	595	90 Pr	Prickly. Bristles vestiges. Homozygous semilethal.
556	50± mu	Mussed. Wings thin, crumpled.	596	90.2 m(3)j	Minute(3)j. Extreme Minute.
557	51± ry	Rosy. Eye color deep ruby.	597	90.2 1(3)PR	Lethal with 1n(3R)P. Lethal. Allele of M(3)j.
558	52 kar	Karmoisin. Eye color like st but duller. Ocelli colorless.	598	91± tx	Taxi. Wings divergent.
559	55± C3G	Crossover suppressor in 3 of Gowen. Eliminates crossing over.	599	91.1 ro	Rough. Eyes rough, small.
560	55.5± red	Red. Red malpighian tubules.	600	91.8 1(3)XaR	Lethal(3)XaR. Balancer of T(2;3)Xa.
561	56.7 jvl	Javelin-like. Bristles cylindrical, crooked.	601	93± cmp	Crumpled. Wings smaller, crumpled.
562	57.9 cv-c	Crossveinless-c. Posterior crossvein absent or reduced.	602	93.8 Bd	Beaded. Wing margins excised. Homozygous lethal.
563	58.2 Sb	Stubble. Bristles short, thick. Homozygous lethal.	603	94.1 Pw	Pointed-wing. Wings pointed at tip. Homozygous lethal.
564	58.5 ss	Spineless. Bristles very small.	604	95± bf	Brief. Body small, bristles Minute-like. Male sterile.
565	58.8 bx	Bithorax. Balancers wing-like. Metathorax resembles mesothorax.	605	95.4 rad	Raised. Wings rise straight up.
566	59.5± cal	Coal. Black body color, similar to e ⁴ .	606	95.5 suB-pr	Suppressor of purple. Male sterile.
567	59± Rf	Roof. Wings drooping at sides.	607	97.3 ra	Rase. Bristles, hairs smaller, fewer.
568	59.9 fl	Fluted. Wings creased, darkish.	608	99.3± Dp	Duplication. Similar to Ultra Bar.
569	62 sr	Stripe. Dark dorsal stripe.	609	100± ld	Loboid. Eyes lobe-like.
570	62.4 M(3)f	Minute(3)f. Minute type.	610	100.7 ca	Claret. Eye color clear ruby.
571	63.1 gl	Glass. Eye color dilute. Facets fused.	611	101 M(3)l	Minute(3)l. Medium Minute.
572	64± gl-1	Glass-like. Eye color orange, eyes rough, small.	612	104.3 bv	Brevis. Bristles short, stubby.
573	64± k	Kidney. Eyes kidney shaped.	613	106.2 M(3)g	Minute(3)g. Slight Minute. Requires E-M(3)g.
574	64± M(3)S35	Minute(3)Schultz'35. Extreme Minute.	Chromosome IV (Element F)		
575	64.5± sed	Sepiaoid. Eye color chocolate.	614	0 ci	Cubitus-interruptus. Vein L4 interrupted.
576	65± cv-d	Crossveinless-d. Posterior crossvein absent or reduced.	615	0- M-4	Minute-4. Medium Minute. Deficiency for ci, ar, gvl and Scn.
577	66± Cur	Curl. Curly wings. Homozygous lethal.	616	0- ar	Abdomen rotatum. Abdomen twisted clockwise.
578	66.2 Dl	Delta. Veins thick at margin. Homozygous lethal.	617	0.2 gvl	Grooveless. Scutellar groove diminished.
579	69.5 H	Hairless. Some bristles and hair. Homozygous lethal.	618	1.4 bt	Bent. Wings bent, legs knobby.
580	70.7 e	Ebony. Body color black.	619	2 ey	Eyeless. Eye small or absent.
581	72.5 det	Detached. Crossveins broken, wings folded under.	620	3 sv	Shaven. Abdominal bristles fewer.
582	75.7 cd	Cardinal. Eye color dull scarlet, ocelli white.			
583	76.2 wo	White ocelli. Ocelli colorless.			
584	77.5± obt	Obtuse. Wings short, blunt.			
585	79.1 bar-3	Bar-3. Phenotype like B/B.			

85. LINKAGE GROUPS: CORN AND TOMATO

Symbols for genes are capitalized only when characterized by dominance. Numbers in brackets are footnote references.

Locus	Symbol	Phenotype [1]	Locus	Symbol	Phenotype [1]
Corn (<i>Zea mays</i>)			Corn (<i>Zea mays</i>) (continued)		
Chromosome I			Chromosome I (continued)		
1	0 sr	Striate leaves.	4	25 ms ₁₇	Male sterile.
2	15 ga ₆	Gametophyte viability factor.	5	27 ts ₂	Tassel seed. Terminal inflorescence with pistillate flowers.
3	21 zb ₄	Zebra striping. Leaves with alternating transverse bands of green and whitish sectors.	6	28 P	Pericarp color.

/1/ Certain of the phenotypes, e.g., virescent and tassel seed, occur more than once. Descriptions are given only for the first listing.

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85. LINKAGE GROUPS: CORN AND TOMATO (Concluded)

Locus Symbol Phenotype [1]			Locus Symbol Phenotype [1]		
Corn (Zea mays) (continued)			Corn (Zea mays) (continued)		
Chromosome I (continued)			Chromosome VII (concluded)		
7 30	z1	Zygotic lethal.	74 60	Bn	Brown endosperm color.
8 53	as	Asynaptic. Chromosomes unpaired at meiosis.	75 96	bd	Branched silkless. Ears branched without silks.
9 66	hm	Helminthosporium susceptibility.	Chromosome VIII		
10 80	br	Brachytic. Stalk has short internodes.	76 0	v16	Virescent seedling.
11 84	Vg	Vestigial glumes.	77 14	ms8	Male sterile.
12 85	f1	Fine striped (green-white) leaves.	78 28	j1	Japonica striping.
13 107	an1	Anther ear. Stamens develop in pistillate inflorescence.	Chromosome IX		
14 128	Kn	Knotted leaves. Wart-like growths on leaves and stalk.	79 0	Dt	Dotted (controller of a1 mutability).
15 134	gs1	Green striped. Leaves with light green stripes between vascular bundles.	80 7	yg2	Yellow-green. Seedlings and plants of yellow-green color.
16 157	Ts6	Tassel seed.	81 26	C	Aleurone color.
17 161	bm2	Brown midrib. Brown pigment in midrib.	82 29	sh1	Shrunken endosperm.
Chromosome II			83 31	bz	Bronze aleurone and plant color.
18 0	ws3	White sheath. Leaf sheaths and stalk deficient in chlorophyll.	84 44	bp	Brown pericarp color.
19 4	al	Albescence. Seedlings become whitish.	85 59	wx	Waxy endosperm.
20 11	lg1	Liguleless. Absence of ligule on leaves.	86 66	pg12	Pale green.
21 30	gl2	Glossy seedling.	87 71	v1	Virescent seedling.
22 49	B	Anthocyanin booster.	88 74	bk2	Brittle stalk.
23 56	sk	Silkless. Ears without silks.	89 106	Wc	White cap of endosperm.
24 68	fl1	Floury endosperm.	Chromosome X		
25 74	ts1	Tassel seed.	90 0	Rp	Resistance to Puccinia.
26 83	v4	Virescent. Young seedlings deficient in chlorophyll.	91 16	Og	Old gold striping. Leaves green-yellow striped.
27 128	Ch	Chocolate pericarp.	92 28	li	Lineate. Leaves with fine longitudinal striations.
Chromosome III			93 38	la	Luteus seedling. Yellow seedlings.
28 0	cr1	Crinkly leaves.	Tomato (Lycopersicon esculentum) [2]		
29 18	d1	Dwarf.	Chromosome I (Linkage Group III)		
30 32	rt	Rootless.	94 0	br	Brachytic.
31 38	Lg3	Liguleless.	95 30	y	Colorless fruit skin.
32 40	Rg	Ragged leaves. Leaves appear split and torn from development of necrotic areas.	96 65	Cf1	Resistance to Cladosporium.
33 47	ts4	Tassel seed.	Chromosome 2 (Linkage Group I)		
34 64	ba1	Barren stalk. No ear produced.	97 0	dv	Dwarf virescent.
35 75	na1	Nana (dwarf).	98 6	m	Mottled leaves.
36 103	a1	Anthocyanin.	99 11	d	Dwarf plant.
37 103-	sh2	Shrunken endosperm.	100 14	p	Peach.
38 115	et	Etched endosperm.	101 22	ro	Rosette.
39 121	ga7	Gametophyte factor.	102 25	ps	Positional sterile.
Chromosome IV			103 30	O	Oval fruit.
40 0	de1	Defective endosperm.	104 32	aw	Without anthocyanin.
41 35	Ga1	Gametophyte factor.	105 48	Wo	Woolly plant.
42 56	Ts5	Tassel seed.	106 53	s	Compound inflorescence.
43 66	sp1	Small pollen.	107 60	ne	Necrotic leaves.
44 71	su1	Sugary endosperm.	108 61	bk	Beaked fruits.
45 74	de16	Defective endosperm.	109 77	lc	Few fruit loculi.
46 84	zb6	Zebra striping.	Chromosome 7 (Linkage Groups X and XII)		
47 100	Tu	Tunicate (pod corn). Enlarged glumes in male and female inflorescences.	110 0	wt	Wilty foliage.
48 105	j2	Japonica striping. Leaves green-white striped.	111 30	n	Nipple-tipped fruit.
49 111	gl3	Glossy seedling.	Chromosome 8 (Linkage Groups VI and VIII)		
Chromosome V			112 0	al	Anthocyanin loser.
50 0	gl17	Glossy seedling.	113 40	dl	Dialytic stamens.
51 1	a2	Anthocyanin.	114 49	bu	Bushy.
52 7	bm1	Brown midrib.	115 76	l	Lutescent foliage.
53 8	bt1	Brittle endosperm.	Chromosome 9		
54 11	v3	Virescent seedling.	116 0	wd	Wilty dwarf.
55 13	bv	Brevis (dwarf) plant.	Chromosome 10 (Linkage Group VII)		
56 32	pr	Red aleurone color.	117 0+	pe	Sticky fruit epidermis.
57 41	ys	Yellow stripe. Leaves green-yellow striped.	118 8	lg	Light green foliage.
58 73	v2	Virescent seedling.	119 36	u	Uniform-ripening fruit.
Chromosome VI			120 60	H	Hairs absent.
59 0	po	Polymitotic. Spores undergo extra meiotic-like divisions. Plants are male sterile.	121 75	t	Tangerine fruit color.
60 13	Y	Yellow endosperm color.	122 98	Xa	Xantha seedling.
61 33	pg11	Pale green. Light green seedlings and plants.	Linkage Group II		
62 44	P1	Purple plant.	123 0	r	Yellow fruit flesh.
63 45	Bh	Blotched aleurone.	124 15	wf	White flower.
64 54	sm	Salmon silk.	Linkage Group IV		
65 64	py	Pigmy. Dwarf plant.	125 0	c	Potato leaf.
Chromosome VII			126 17	sp	Self-pruning (determinate habit).
66 0	o2	Opaque endosperm.	127 43	Cf2	Cladosporium resistance.
67 4	in	Intensifier of aleurone color.	Linkage Group V		
68 8	v5	Virescent seedling.	128 0	bi	Bifurcate inflorescence.
69 22	ra1	Ramosa. Branching of ear and tassel.	129 4	f	Fasciated fruit.
70 26	gl1	Glossy seedling.	130 29	a	Anthocyanin absent.
71 36	Tp	Toepod. Plant with many tillers and narrow leaves. Ears and tassels have enlarged bracts.	131 49	hl	Hairless.
72 40	sl	Slashed leaves.	132 69	j	Jointless (also leafy inflorescence).
73 42	ij	Iojap. Leaves green-white striped.	133 86	Cf3	Cladosporium resistance.
Linkage Group XI			134 0	e	Entire leaves.
Linkage Group IX			135 28	w1	Wiry foliage.
Unnumbered Linkage Group			Linkage Group IX		
			136 0	dm	Dwarf modifier.
			Unnumbered Linkage Group		
			137 0	tf	Trifoliate.
			138 11	Fw	Furrowed cotyledons.

/1/ Certain of the phenotypes, e.g., virescent and tassel seed, occur more than once. Descriptions are given only for the first listing. /2/ Chromosome numbers are based on the identification of pachytene chromosomes according to length and, for this reason, certain chromosomes embrace more than one linkage group and do not always correspond to the linkage group numbers.

86. FERTILITY AND INFERTILITY: HYBRIDS

Part I: HYBRIDS REPORTED: PLANT AND ANIMAL KINGDOM

Plants	Number	Animals	Number	Animals (concluded)	Number
1 Thalophytes	55	5 Echinoderms	30	9 Amphibia	52
2 Bryophytes	6	6 Mollusca	2	10 Reptiles	37
3 Pteridophytes	158	7 Arthropoda	240	11 Birds	400
4 Spermatophytes	8946 ¹	8 Fish	154	12 Mammals	300

/1/ Exclusive of the orchids.

Part II: MAMMALS AND BIRDS

Parental Species		Sex Ratio		Hybrid Fertility	
Female	Male	% Males ¹		Male	Female
Mammals					
1 Bison, American (Bison bison)	Cattle, bull (Bos taurus)	31		Infertile	Fertile
2 Cattle, Brahma (Zebu) (B. taurus [indicus])	Gayal, Indian (Bibos frontalis)			Infertile	Fertile
3 Cattle, cow (B. taurus)	Bison, American (Bos americanus)	15.7		Infertile	Fertile
4 Cattle, cow (B. taurus)	Yak (B. grunniens)	36		Infertile ²	Fertile
5 Guinea pig (Cavia porcellus)	Guinea pig, Peruvian (Cavia cutleri)			Fertile	Fertile
6 Horse (Equus caballus)	Ass (donkey) (Equus asinus)	44.4		Infertile	Fertile ³
7 Horse (E. caballus)	Zebra (E. grevyi)			Infertile	Fertile
8 Mouse, Asiatic (Mus bactrianus)	Mouse, house (Mus musculus)	48.3		Fertile	Fertile
9 Mouse, house (M. musculus)	Mouse, Asiatic (M. bactrianus)	50.7		Fertile	Fertile
10 Yak (Bos grunniens)	Cattle, bull (Bos taurus)			Infertile ²	Fertile
Birds					
11 Chicken (Gallus domesticus)	Guinea fowl (Numida meleagris)			Infertile	
12 Chicken (G. domesticus)	Pheasant, common (Phasianus colchicus)	99.1		Infertile	
13 Chicken (G. domesticus)	Pheasant, ring-neck (P. torquatus)	88.5		Infertile	Infertile
14 Dove, dwarf turtle (Streptopelia humilis)	Dove, ring (Streptopelia risoria)	50		Fertile	Fertile
15 Dove, European turtle (S. turtur)	Dove, oriental turtle (S. orientalis)			Fertile	?
16 Dove, Oriental turtle (S. orientalis)	Dove, European turtle (S. turtur)			Fertile	Fertile
17 Dove, Oriental turtle (S. orientalis)	Dove, ring (S. risoria)	58.1		Fertile ⁴	Fertile ⁴
18 Dove, Oriental turtle (S. orientalis)	Pigeon, common (Columba livia)			Fertile ³	?
19 Dove, ring (S. risoria)	Dove, dwarf turtle (Streptopelia humilis)	45.4		Fertile	Fertile
20 Dove, ring (S. risoria)	Dove, European turtle (S. turtur)	48.8		Fertile ⁴	Fertile ⁴
21 Dove, ring (S. risoria)	Dove, mourning (Zenaidura carolinensis)	100		Infertile	
22 Dove, ring (S. risoria)	Dove, pearl neck (Streptopelia chinensis)	57.8		Fertile	Fertile ⁴
23 Dove, ring (S. risoria)	Dove, Senegal (S. senegalensis)	50		Fertile ⁴	Fertile ⁴
24 Dove, ring (S. risoria)	Pigeon, common (Columba livia)	97.2		Fertile ³	Infertile
25 Dove, ring (S. risoria)	Pigeon, passenger (Ectopistes migratorius)			Infertile	
26 Duck, mallard (Anas platyrhynchos)	Duck, dusky (Anas fulvigula)	54.8		Fertile	Fertile
27 Duck, mallard (A. platyrhynchos)	Duck, muscovy (Cairina moschata)	56.1		Infertile	Infertile
28 Duck, muscovy (Cairina moschata)	Duck, mallard (Anas platyrhynchos)	54.6		Infertile	Infertile
29 Grouse, European wood (Tetrao urogallus)	Grouse, European black (Lyrurus tetrix)	83.3		Fertile ⁵	Fertile ⁵
30 Pheasant, golden (Chrysolophus pictus)	Pheasant, Lady Amherst's (Chrysolophus amherstiae)	43.9		Fertile	Fertile
31 Pheasant, Reeves (Phasianus reevesi)	Pheasant, ring-neck (Phasianus torquatus)	91.7		Infertile	Infertile
32 Pheasant, ring-neck (P. torquatus)	Chicken (Gallus domesticus)	49.7		Infertile	Infertile
33 Pigeon, common (Columba livia)	Pigeon, European stock (Columba oenas)			Fertile	Fertile
34 Pigeon, common (C. livia)	Pigeon, triangular spotted (C. guinea)			Fertile ⁵	Fertile ⁵

/1/ Sex ratios are given only where the total number of hybrid offspring is a minimum of 25. Hybrid sex determined after hatching. /2/ Usually.

/3/ Rarely. /4/ Partially. /5/ Low.

Part III: INSECTS

Part III: INSECTS										
Parental Species		Sex Ratio	Hybrid Fertility			Parental Species		Sex Ratio	Hybrid Fertility	
Female	Male	% Males ¹	Male	Female		Female	Male	% Males ¹	Male	Female
Moths and Butterflies						Fruitflies				
1	<i>Amorpha austauti</i>	<i>Smerinthus atlanticus</i>	90			22	<i>Drosophila aldrichi</i>	<i>Drosophila arizonensis</i>		Infertile
2	<i>A. austauti</i>	<i>S. ocellata</i>	93			23	<i>D. algonquin</i>	<i>D. athabasca</i>		Infertile
3	<i>A. populi</i>	<i>S. ocellata</i>	98			24	<i>D. arizonensis</i>	<i>D. mojavensis</i>		Infertile
4	<i>Clostera curtula</i>	<i>Clostera anachoreta</i>		Fertile	Sterile	25	<i>D. azteca</i>	<i>D. athabasca</i>		Infertile
5	<i>Deilephila galli</i>	<i>Chaerocampa elpenor</i>	>71			26	<i>D. melanogaster</i>	<i>D. simulans</i>		Infertile
6	<i>Lycia hirtaria</i>	<i>Nyssia zonaria</i>	39.3	Fertile	Infertile	27	<i>D. melanogaster</i>	<i>D. neorepleta</i>		Fertile
7	<i>L. hirtaria</i>	<i>Poecilopsis pomonaria</i>	75.6	Fertile	Infertile	28	<i>D. miranda</i>	<i>D. persimilis</i>	50	Infertile
8	<i>Nyssia graecaria</i>	<i>Lycia hirtaria</i>	100	Infertile		29	<i>D. miranda</i>	<i>D. pseudoobscura</i>	50	Infertile
9	<i>N. zonaria</i>	<i>L. hirtaria</i>	100	Infertile		30	<i>D. mojavensis</i>	<i>D. arizonensis</i>		Fertile
10	<i>N. zonaria</i>	<i>Poecilopsis lapponaria</i>	98.1			31	<i>D. montana</i>	<i>D. texana</i>	90.9	Fertile
11	<i>N. zonaria</i>	<i>P. pomonaria</i>	95.8			32	<i>D. mulleri</i>	<i>D. aldrichi</i>		Infertile
12	<i>Oporabia autumnata</i>	<i>Oporabia dilutata</i>	52.5	Fertile	Infertile	33	<i>D. mulleri</i>	<i>D. arizonensis</i>	100	Infertile
13	<i>Poecilopsis isabellae</i>	<i>Lycia hirtaria</i>	54.3	Fertile	Infertile	34	<i>D. mulleri</i>	<i>D. mojavensis</i>		Infertile
14	<i>P. lapponaria</i>	<i>Poecilopsis pomonaria</i>	49.3	Fertile	Infertile	35	<i>D. munda</i>	<i>D. occidentalis</i>	55.5	Fertile
15	<i>P. pomonaria</i>	<i>Lycia hirtaria</i>	51.5	Fertile	Fertile	36	<i>D. munda</i>	<i>D. subquinaria</i>	49.6	Infertile
16	<i>P. pomonaria</i>	<i>Nyssia zonaria</i>	30.1			37	<i>D. pseudoobscura</i>	<i>D. miranda</i>		Infertile
17	<i>Saturnia pyri</i>	<i>Saturnia pavonia</i>	51.4	Fertile	Infertile	38	<i>D. pseudoobscura</i>	<i>D. persimilis</i>	48.2	Infertile
18	<i>S. spini</i>	<i>S. pavonia</i>	53	Fertile	Infertile	39	<i>D. simulans</i>	<i>D. melanogaster</i>		Infertile
19	<i>Smerinthus ocellata</i>	<i>Calasymphylus astylus</i>	100			40	<i>D. texana</i>	<i>D. montana</i>	50.5	Fertile
20	<i>Tephrosia bistortata</i>	<i>Tephrosia crepuscularia</i>	96.9	Fertile	Fertile	41	<i>D. virilis</i>	<i>D. americana</i>		Fertile
21	<i>T. crepuscularia</i>	<i>T. bistortata</i>	48.9	Fertile	Fertile	42	<i>D. virilis</i>	<i>D. montana</i>	49.8	Fertile

/1/ Sex ratios are given only where the total number of hybrid offspring is a minimum of 25. Hybrid sex determined after hatching. /2/ Rarely.

Part IV: PLANTS

SP = self pollination; CP = cross pollination; S = sterile; F = fertile; P = partially fertile; M = moderate.

Parental Species		Compatibility		Parental Species		Compatibility	
		Parents	Hybrid			Parents	Hybrid
Tomato (Lycopersicon species)							
1 L. esculentum x L. esculentum	SP-F; CP-F			9 L. glandulosum x L. peruvianum	CP-F		CP-S; CP-F
2 L. esculentum x L. glandulosum ¹	CP-S			10 L. glandulosum x L. pimpinellifolium ³	CP-S		
3 L. esculentum x L. hirsutum	CP-F			11 L. hirsutum x L. hirsutum	SP-S		CP-S; CP-F
4 L. esculentum x L. h. glabratum	CP-F			12 L. hirsutum x L. pimpinellifolium	SP-F		SP-P; CP-F
5 L. esculentum x L. peruvianum ^{1,2}	CP-S			13 L. h. glabratum x L. h. glabratum	SP-F; CP-F		SP-F; CP-F
6 L. esculentum x L. pimpinellifolium	CP-F			14 L. peruvianum x L. peruvianum	SP-S; CP-F		SP-S; CP-F
7 L. esculentum x L. pisisi ¹	CP-S			15 L. peruvianum x L. pisisi	CP-S		
8 L. glandulosum x L. glandulosum	SP-S; CP-F			16 L. pimpinellifolium x L. pimpinellifolium	SP-F; CP-F		SP-F; CP-F

/1/ Hybrids obtainable from embryo culture, occasionally without. /2/ L. peruvianum var. dentatum (L. chilense) will cross with L. esculentum without embryo culture and the F₁ will backcross more readily than other varieties of L. peruvianum. /3/ Hybrids probably obtainable with embryo culture.

86. FERTILITY AND INFERTILITY: HYBRIDS (Concluded)

Part IV: PLANTS (Concluded)

SP = self pollination; CP = cross pollination; S = sterile; F = fertile; P = partially fertile; M = moderate.

Parental Species		Compatibility		Parental Species		Compatibility	
		Parents	Hybrid			Parents	Hybrid
Pepper (Capsicum species)							
17	C. annuum x C. annuum	SP-F; CP-F	SP-F; CP-F	27	C. frutescens x C. pubescens	SP-S	
18	C. annuum x C. pubescens	CP-S		28	C. frutescens x C. pendulum	SP-F	SP-S; CP-MS
19	C. annuum x C. frutescens	CP-F ⁴	SP-MS; CP-MS	29	C. pendulum x C. pendulum	SP-F; CP-F	SP-F; CP-F
20	C. annuum x C. pendulum	CP-F ⁵	SP-S; CP-S	30	C. pendulum x C. pubescens	CP-S	
21	C. annuum x C. chacoense	CP-F	SP-S; CP-S	31	C. pubescens x C. pubescens	SP-F; CP-F	SP-F; CP-F
22	C. chacoense x C. chacoense	SP-F; CP-F	SP-F; CP-F	32	C. sinensis x C. annuum	CP-F	SP-MS; CP-MS
23	C. chacoense x C. pubescens	CP-S		33	C. sinensis x C. frutescens	CP-F	SP-MS; CP-MS
24	C. chacoense x C. frutescens	CP-F	SP-S; CP-S	34	C. sinensis x C. pendulum	CP-F	SP-S; CP-S
25	C. chacoense x C. pendulum	CP-S ⁴	SP-MS; CP-MS	35	C. sinensis x C. pubescens	CP-F ⁵	SP-S; CP-S
26	C. frutescens x C. frutescens	SP-F; CP-F	SP-F; CP-F	36	C. sinensis x C. chacoense	CP-F ⁴	SP-S; CP-MS
Citrus Species ⁶							
37	C. aurantifolia x C. aurantifolia	SP-P; CP-P	CP-P	51	C. limonia x C. reticulata	CP-F	
38	C. aurantifolia x C. limonia	CP-F		52	C. limonia x P. trifoliata	CP-F	
39	C. aurantifolia x Fortunella japonica	CP-F		53	C. limonia x C. paradisi	CP-F	
40	C. aurantium x C. aurantium	SP-P; CP-P		54	C. paradisi x C. paradisi	SP-P; CP-P	
41	C. aurantium x Poncirus trifoliata	CP-F		55	C. paradisi x C. reticulata	CP-F	SP-S; CP-F
42	C. grandis x C. grandis	SP-P; CP-P		56	C. paradisi x C. sinensis	CP-F	
43	C. grandis x C. aurantium	CP-F		57	C. reticulata x C. reticulata	CP-F ⁷	CP-F
44	C. grandis x C. reticulata	CP-F		58	C. reticulata x F. japonica	CP-F	
45	C. grandis x C. medica	CP-F		59	C. reticulata x P. trifoliata	CP-F	CP-F
46	C. grandis x C. sinensis	CP-F		60	C. reticulata x C. sinensis	CP-F	CP-F
47	C. grandis x C. paradisi	CP-F	61	C. reticulata x C. ichangensis	CP-F		
48	C. ichangensis x Poncirus trifoliata	CP-F	62	C. sinensis x C. sinensis	SP-P; CP-P		
49	C. limonia x C. limonia	SP-P; CP-P	63	C. sinensis x P. trifoliata	CP-F	SP-P ⁸ ; CP-P	
50	C. limonia x C. sinensis	CP-F	64	F. japonica x P. trifoliata	CP-F		

/4/ Slightly. /5/ With embryo culture. /6/ Lime (Citrus aurantifolia), orange (C. aurantium), grapefruit (C. grandis), Citrus sp (C. ichangensis), lemon (C. limonia), citron (C. medica), grapefruit (C. paradisi), orange (C. reticulata), orange (C. sinensis), kumquat (Fortunella japonica), trifoliolate orange (Poncirus trifoliata). /7/ A few varieties are self and cross incompatible. /8/ Some.

87. HYBRID VIGOR: CORN

Values in parentheses are estimates "b" of the 95% range (cf Introduction).

Part I: COMPARATIVE GROWTH RATES IN RECIPROCAL CROSS: ENDOSPERM AND EMBRYO

Days after Pollination		Dent ¹		Dent x Pop		Pop x Dent		Pop	
		Endosperm	Embryo	Endosperm	Embryo	Endosperm	Embryo	Endosperm	Embryo
1	12	0.2878	0.004	0.3684	0.006	0.245	0.001	0.215	0.001
2	16	1.0449	0.043	1.0668	0.049	0.585	0.020	0.556	0.012
3	20	2.0829	0.457	2.639	0.240	1.375	0.105	1.323	0.084
4	24	3.7549	0.493	3.938	0.556	1.915	0.221	1.904	0.153
5	28	5.1712	0.938	5.536	0.915	2.427	0.333	2.451	0.250
6	32	5.3761	1.081	5.997	1.074	3.089	0.449	2.894	0.315
7	36	5.6709	1.124	6.243	1.214	3.617	0.531	2.963	0.326
8	40	6.5997	1.541	7.438	1.409	3.662	0.566	3.343	0.395
9	44	7.0252	1.646	8.408	1.734	3.888	0.613	3.674	0.459
10	48	6.7793	1.702	8.541	1.724	4.341	0.705	3.398	0.483
11	52	7.3842	2.016	9.580	2.114	4.117	0.684	3.594	0.452
12	Harvest ²	0.1805	0.0543	0.2171	0.0533	0.1059	0.0195	0.0925	0.0132

/1/ Individual harvest weights based on 50 kernel samples. /2/ Date and weight, linear component.

Part II: EFFECT OF CONTINUED INBREEDING ON REDUCTIONS IN HEIGHT AND YIELD: THREE INBRED LINES

Generations, Number Inbred	Line 1-6		Line 1-7		Line 1-9	
	Height in.	Yield/Acre, bushels	Height in.	Yield/Acre, bushels	Height in.	Yield/Acre, bushels
1	0	117	81(74-88)	117	81(74-88)	117
2	1-5	87	64(53-75)	81	51(44-58)	77
3	6-10	97(96-98)	45(33-57)	84(83-85)	36(31-41)	82(80-84)
4	11-15	97(94-100)	38(34-42)	84(82-86)	34(31-37)	83(81-85)
5	16-20	88(84-92)	22(18-26)	85(82-88)	24(21-27)	75(71-79)
6	21-25	81(79-83)	20(14-26)	75(72-78)	21(18-24)	71(68-74)
7	26-30	92(89-95)	24(15-33)	78(82-82)	18(14-22)	77(74-80)

Part III: RELATIVE AVERAGE YIELDS: INBRED LINES AND DIALLEL F₁ CROSSES¹

Varieties	F ₁ Hybrids ²	Inbred	Varieties	F ₁ Hybrids ²	Inbred	Varieties	F ₁ Hybrids ²	Inbred
1 B2	87.4(81.4-93.4)	39.0(35.8-42.2)	4 OhO7	83.9(77.9-89.9)	28.5(25.3-31.7)	8 Hy	75.5(69.7-81.7)	31.9(28.7-35.1)
2 38-11	86.5(80.5-92.5)	26.5(23.3-29.7)	5 WF9	81.6(75.6-87.6)	28.5(25.3-31.7)	9 WV7	73.5(67.5-79.5)	20.1(16.9-23.3)
3 K159	86.3(80.3-92.3)	49.8(46.6-53.0)	6 R46	80.3(74.3-86.3)	39.8(36.6-43.0)	10 C.I.14	68.1(62.1-74.1)	2.7(0-5.9)
			7 OhO4	75.7(69.7-81.7)	15.1(11.9-18.3)			

/1/ Values, bushels/acre. /2/ All possible.

Part IV: DECREASE IN YIELDING CAPACITY, ADVANCED HYBRID GENERATIONS

Specification	Average Yield, bushels/acre		Average Difference, F ₁ -P ₁	Yield F ₂ bushels/acre		Loss of Vigor, Grain Yield	
	F ₁	P ₁		Actual	Expected	Actual bushels	Expected bushels
1 10 single hybrids	62.8	23.74	39.06	44.2	43.3	18.6	19.5
2 4 three-way hybrids	64.2	23.75	40.45	49.3	50.7	14.9	13.5
3 10 double hybrids	64.1	25.00	39.10	54.0	54.3	10.1	9.8

Part V: EFFECT ON YIELD AND PLANT HEIGHT: VARIOUS LEVELS OF HETEROZYGOSITY

Degree of Heterozygosity, %	Type of Combination	Number of Entries	Grain Yield, bushels/acre		Ear Node, Height, in.	
			Actual	Predicted ¹	Actual	Predicted
1	0	Inbred lines sibbed	41.5(40.57-42.43)		25.5(24.86-26.14)	
2	50	F ₂ single crosses	62.2(60.18-64.22)	63.2(61.94-64.46)	32.8(32.08-33.52)	33.0(32.59-33.41)
3		Backcrosses	67.9(65.42-70.38)	63.2(61.94-64.46)	32.5(31.90-33.10)	33.0(32.59-33.41)
4	75	(A x B) (A x C)	75.2(73.14-77.26)	74.1(72.61-75.59)	38.4(37.62-39.18)	36.1(35.71-36.49) ¹
5	100	Single crosses	84.9(82.55-87.25)		39.6(39.06-40.14)	
6		Three-way crosses	84.9(82.46-87.34)	84.9(82.55-87.25)	40.5(39.90-41.10)	39.6(39.06-40.14) ¹
7		Double crosses	81.9(80.37-83.43)	84.9(82.55-87.25) ¹	40.9(40.01-41.79)	39.6(39.06-40.14) ¹

/1/ Differs significantly from actual.

88. HERITABILITY ESTIMATES: FARM ANIMALS

Values are from the best available information; however, the inadequacies of heritability estimates should be remembered in using this table. Values in parentheses, unless otherwise noted, are estimate "d" of the 95% range (cf Introduction).

Part I: CHICKENS AND TURKEYS

Characteristic	Method of Estimation ¹				Characteristic	Method of Estimation ¹			
	h ² S	h ² D	h ² DS	h ² o.d.		h ² S	h ² D	h ² DS	h ² o.d.
Chickens ²					Chickens (concluded) ²				
1 Body weight, 8 wk (NH)	(16-39)		(32-50)	45	48 Albumin weight (WL)			110	
2 Body weight, 8 wk (BPR)	(31-32)		(33-60)	39	49 Albumin weight (Composite)			22	
3 Body weight, 8 wk (Composite)			46	40	50 Yolk weight (NH)			0	
4 Body weight, 10 wk (W. Wyan.)		(20-63)			51 Yolk weight (BPR)			2	
5 Body weight, 10 wk (Composite)			46	33	52 Yolk weight (WL)			20	
6 Body weight, 12 wk (SCWL)	20				53 Shell texture (Composite)			27	
7 Body weight, 12 wk (NH)	42	60	51		54 Shell thickness (Composite)			27	
8 Body weight, 22 wk (WL)	27				55 Blood spots (WL)			67	46
9 Body depth (NH)	11		43		Turkeys ²				
10 Keel length (NH)	(27-50)	17	(34-37)		56 Body weight, 2 wk (MW)	σ28913	σ37976	σ69973	
11 Breast width (NH)	13	29	21		57 Body weight, 4 wk (MW)	σ4	σ37976	σ20938	
12 Shank length (NH)	50	48	(33-49)		58 Body weight, 4 wk (BBB)	σ49938		σ40944	
13 Shank length (WL)			(33-54)		59 Body weight, 4 wk (BSW)			σ26919	
14 Thyroid weight (NH)			48		60 Body weight, 8 wk (MW)	σ19932	σ21972	σ20938	
15 Testes weight (NH)			29		61 Body weight, 8 wk (BBB)	σ56928		σ45945	
16 Feathering, 8 wk (NH)			33		62 Body weight, 8 wk (BSW)	σ1198		σ33916	
17 Feathering, 8 wk (BPR)			42		63 Body weight, 14 wk (BBB)	σ72939		σ62929	
18 Egg production ³ (WL)	21	22	(15-22)	(9-16)	64 Body weight, 14 wk (BSW)	σ6918		σ19916	
19 Egg production ³ (BPR)		41	25	30	65 Body weight, 16 wk (MW)	σ46921	σ27967	σ36944	
20 Rate, Dec. to Mar. (Composite)			41	11	66 Body weight, 16 wk (WH)	σ23959	σ62942	σ42950	σ62941
21 Rate, Mar. to June (Composite)			38	0	67 Body weight, 24 wk (MW)	σ38929	σ1292	σ25916	
22 Rate, Dec. to June (Composite)			51	0	68 Body weight, 24 wk (WH)	σ33961	σ68970	σ51960	σ68959
23 Production Index (WL)	23	10	16	57	69 Body weight, 25 wk (BBB)	σ34929	σ2971	σ18950	
24 Sexual maturity (WL)	(24-27)	17	(31-33)	(31-35)	70 Body weight, 25 wk (WH)	σ29924	σ71971	σ50947	
25 Sexual maturity (Composite)			20	(7-26)	71 Body weight, 26 wk (BBB)	σ52929		σ52925	
26 Pause, 6 da (Composite)			(16-20)	(21-23)	72 Body weight, 26 wk (BSW)	σ13919		σ20924	
27 Pause, winter (WL)	8 ⁴				73 Breast width, 26 wk (BBB)	σ494		σ23913	
28 Persistency (Composite)			10		74 Breast width, 26 wk (BSW)			σ37940	
29 Persistency (WL)	5 ⁴				75 Breast depth, 26 wk (BBB)	σ22921		σ30940	
30 Total mortality ⁵ (Composite)			12		76 Breast depth, 26 wk (BSW)			σ41921	
31 Total mortality ⁶ (WL)	8	11	8		77 Keel length, 26 wk (BBB)	σ32915		σ22918	
32 Leukosis mortality (WL)	5	3	8		78 Keel length, 26 wk (BSW)			σ-5914	
33 Reproductive disorders (WL)	2	6			79 Shank length, 26 wk (BBB)	σ25		σ34	
34 Hatchability (Composite)				16	80 Shank length, 26 wk (BSW)			σ52	
Egg weight ⁷					81 Egg production, Feb-June (B)				92
35 Sexual maturity ⁸ (WL)	60		50	(44-61)	82 Egg production, Feb-June (BSW)				911
36 Nov. (10 eggs) (WL)	48		36	61	83 Egg production, Feb-June (BBB)	99		914	916
37 March (1 egg) (Composite)			52	52	84 Egg production, Feb-June (WH)	929	927	928	
38 April (10 eggs) (WL)			47	39	85 Egg weight, Feb. (10 eggs) (BBB)	953		950	964
39 April (10 eggs) (Composite)			61	61	86 Egg weight, May (10 eggs) (WH)	922	962	942	
40 Jan. to May ⁹ (WL)	37 ⁴			55	87 Fertility, 1-7 da ¹¹ (BBB)		953	926	
41 Dec. to May ¹⁰ (NH)			67		88 Fertility, 8-14 da ¹¹ (BBB)		926	912	
42 Dec. to May ¹⁰ (BPR)			40		89 Fertility (BBB)			930	
43 Dec. to May ¹⁰ (WL)			93		90 Hatchability, 1-7 da (BBB)	93		913	940
44 Dec. to May ¹⁰ (Composite)				50	91 Hatchability, 8-14 da (BBB)	914		921	926
45 Shell color (BPR; RIR)	30	91	58	78	92 Hatchability, Feb-June (B)				933
46 Albumin weight (NH)			83		93 Hatchability, Feb-June (BSW)				91
47 Albumin weight (BPR)			14						

/1/ h²S = paternal half sib correlation; h²D = maternal half sib correlation; h²DS = full sib correlation; h²o.d. = offspring-dam regression.

/2/ Breeds and varieties are denoted in parentheses. For chickens: NH = New Hampshire, BPR = Barred Plymouth Rock, WL = White Leghorn, SCWL = Single Comb White Leghorn, W. Wyan. = White Wyandotte, RIR = Rhode Island Red, Composite = composite of several breeds. For turkeys: MW = Medium White, BBB = Broad Breasted Bronze, B = Bronze, BSW = Beltsville Small White, WH = White Holland. /3/ Annual egg production of survivors. /4/ Method of determining estimate not specified. /5/ 319 da after housing. /6/ 1st laying year. /7/ Estimates based on cited number of eggs at specified periods. /8/ 10 eggs. /9/ All eggs. /10/ Representative egg sample. /11/ Stored eggs.

Part II: BEEF AND DAIRY CATTLE

Characteristic		Method of Estimation ¹				Characteristic		Method of Estimation ¹ _b
		P	DO	SO	S			
Beef Cattle ²						Dairy Cattle		
1	Birth weight	48	42	35		13	Birth weight	60 ⁵
2	Gain, birth to weaning	21	7	17		14	Mature weight	60 ⁵
3	Weaning weight	28	10	26		15	Milk production	(25-38)
4	Yearling weight, off pasture	45	39			16	Butterfat production	(17-32)
5	Gain, off pasture	39	18		30	17	Butterfat per cent	(33-57)
6	Final feedlot weight	84		92		18	Type classification rating (overall)	(14-31)
7	Gain in feedlot	64		97	43	19	Amount of spotting (Holsteins)	(93-99)
8	Grade or score at weaning	27	22	11		20	Mastitis resistance	(14-38)
9	Grade or score as yearlings ³	27	14			21	Gestation length	32 ⁵
10	Grade or score at slaughter	46				22	Services per conception	(3-7)
11	Carcass grade	32						
12	Economy of gain	29		48				

/1/ P = paternal half sibs, DO = dam offspring regression, SO = sire offspring regression, S = selection experiments. /2/ Values represent weighted averages (based on volume of data) of published estimates. Not listed are area of eye muscle, 70P, and thickness of fat, 38 P. /3/ Off pasture. /4/ Estimates based on intrasire regression unless otherwise noted. /5/ Average of several methods and/or breeds.

88. HERITABILITY ESTIMATES: FARM ANIMALS (Continued)

Values are from the best available information; however, the inadequacies of heritability estimates should be remembered in using this table. Values in parentheses, unless otherwise noted, are estimate "d" of the 95% range (cf Introduction).

Part III: SHEEP							
Characteristic		Method of Estimation ¹		Characteristic	Method of Estimation ¹		
		p	b		p	b	Average ²
1 Birth weight	30			9 Type score at weaning	15	7	(7-13)
2 Yearling staple length			36	10 Condition score at weaning	2.4	14	(4-21)
3 Yearling weight clean wool			(28-38)	11 Skin folds			(45-51)
4 Yearling body weight			40	12 Neck folds	36	45	(8-39)
5 Yearling body score			12	13 Face covering	51	60	(46-56)
6 Body folds			37	14 Number of nipples		14.4 ³	
7 Weaning weight	27			15 Number of functional nipples		22	
8 Staple length at weaning	41		(34-39)				(17-43)

/1/ p = paternal half sibs, b = intrasire regression. /2/ Average of several methods and/or breeds. /3/ Intrasire correlation.

Part IV: SWINE					
Characteristic	Breed	Estimate of Heritability ¹	Characteristic	Breed	Estimate of Heritability ¹
1 Birth weight	Composite	2 A	66 56-168 da	Not stated	45 A
2 Birth weight	Duroc	0 A	67 84-112 da	Not stated	10 D
3 Birth weight	Duroc	-23 E	68 84-112 da	Duroc	31 A
4 Birth weight	Hampshire	5 A	69 112-140 da	Duroc	4 A
5 Birth weight	Hampshire	6 D	70 112-140 da	Not stated	10 D
6 Birth weight	Hampshire	8 E	71 112-154 da	Duroc	25 A
7 Birth weight	Not stated	14 D	72 112-154 da	Crosses	34 A
8 Body weight, 21 da	Duroc	4 A	73 112-168 da	Duroc	17 A
9 Body weight, 21 da	Hampshire	24 A	74 140-168 da	Duroc	13 A
10 Body weight, 21 da	Hampshire	14 D	75 140-168	Not stated	10 D
11 Body weight, 21 da	Hampshire	-4 E	Daily weight gain		
12 Body weight, 21 da	Not stated	-6 D	76 Birth-200 lb	Not stated	21 A
13 Body weight, 56 da	Duroc	15 A	77 Birth-200 lb	Not stated	3 D
14 Body weight, 56 da	Hampshire	17 A	78 56 da - 200 lb	P.C. and Minn. No. 1	31 D
15 Body weight, 56 da	Hampshire	8 D	79 56 da - 200 lb	Not stated	40 A
16 Body weight, 56 da	Hampshire	-2 E	80 56 da - 200 lb	Not stated	21 D
17 Body weight, 56 da	P.C. and Landrace	3 D	81 56 da - 200 lb	Danish Landrace	41 A
18 Body weight, 56 da	P.C. and Minn. No. 1	-20 D	82 56 da - 200 lb	Danish Landrace	46 B
19 Body weight, 60 da	Poland China	7 A	83 56 da - 200 lb	Danish Landrace	-19 F
20 Body weight, 63 da	Duroc	14 D	84 56 da - 200 lb	Danish Landrace	24 O
21 Body weight, 72 da	Duroc	9 E	85 56 da - 225 lb	Duroc	18 A
22 Body weight, 84 da	Duroc	26 A	86 56 da - 225 lb	P.C. and Landrace	31 A
23 Body weight, 112 da	Duroc	28 A	87 56 da - 112 da	Duroc	18 A
24 Body weight, 112 da	Not stated	0 A	88 72 da - 225 lb	Duroc	43 E
25 Body weight, 140 da	Duroc	19 A	89 112 da - 225 lb	Duroc	14 A
26 Body weight, 140 da	Not stated	21 A	90 50 lb - 200 lb	P.C. and Minn. No. 1	26 D
27 Body weight, 150 da	Hampshire	14 A	Sow Productivity		
28 Body weight, 150 da	Hampshire	16 J	91 Litter size at birth	Composite	17 K
29 Body weight, 154 da	Not stated	10 D	92 Litter size at birth	Poland China	17 H
30 Body weight, 154 da	P.C. and Landrace	7 D	93 Litter size at birth	Poland China	18 H
31 Body weight, 154 da	Hampshire	23 D	94 Litter size at birth	Yorkshire	10 H
32 Body weight, 154 da	Hampshire	17 J	95 Litter size at birth	Tamworth	34 H
33 Body weight, 154 da	Hampshire	9 E	96 Litter size at birth	Berkshire	44 H
34 Body weight, 154 da	Composite	19 P	97 Litter size at birth	Chester White	13 K
35 Body weight, 168 da	Duroc	25 A	98 Litter size at birth	P.C. and Landrace	-11 D
36 Body weight, 168 da	Not stated	27 A	99 Litter size at birth	Duroc	25 D
37 Body weight, 180 da	Poland China	20 A	100 Litter size at birth	Duroc	24 K
38 Body weight, 180 da	Poland China	62 D	101 Litter size at birth	German Landrace	14 A
39 Body weight, 180 da	Poland China	30 M	102 Litter size at birth	German grazing hog	12 A
40 Body weight, 180 da	Poland China	40 I	103 Litter size at birth	Duroc	3 D
41 Body weight, 180 da	Poland China	30 D	104 Litter size at birth	Composite	16 A
42 Body weight, 180 da	P.C. and Minn. No. 1	14 D	105 Litter size at birth	Composite	14 D
43 Body weight, 180 da	Duroc	22 D	106 Litter size at birth	Composite	15 I
44 Body weight, 180 da	Duroc	23 N	107 Litter size at birth	Not stated	7 D
45 Body weight, 180 da	Hampshire	24 A	108 Litter size at birth	Duroc	22 K
46 Body weight, 180 da	Hampshire	65 D	109 Litter size at birth	Duroc	28 K
47 Body weight, 180 da	Hampshire	19 J	110 Litter size at birth	Swiss Land. and York.	12 K
48 Body weight, 180 da	Hampshire	5 D	111 Live pigs farrowed	Composite	18 A
49 Body weight, 180 da	Hampshire	22 E	112 Live pigs farrowed	Composite	16 D
50 Body weight, 180 da	Hampshire	16 J	113 Live pigs farrowed	Composite	9 I
51 Body weight, 180 da	P.C. and Landrace	34 A	114 Live pigs farrowed	Duroc	24 D
52 Body weight, 200 da	Yorkshire	27 G	115 Live pigs farrowed	Duroc	21 K
Body weight gain			116 Live pigs farrowed	Composite	22 D
53 Birth-21 da	Duroc	7 A	117 Litter size, 21 da	Duroc	20 D
54 Birth-56 da	Duroc	22 A	118 Litter size, 21 da	Duroc	34 K
55 Birth-56 da	Duroc	15 A	119 Litter size, 21 da	Swiss Land. and York.	7 K
56 Birth-56 da	Crosses	2 A	120 Litter size, 28 da	Chester White	16 K
57 21-56 da	Duroc	15 A	121 Litter size, 56 da	Not stated	6 D
58 21-56 da	Not stated	-2 D	122 Litter size, 56 da	Duroc	19 D
59 56-84 da	Duroc	20 A	123 Litter size, 56 da	Duroc	25 K
60 56-84 da	Not stated	18 A	124 Litter size, 56 da	P.C. and Landrace	-9 D
61 56-84 da	Not stated	6 D	125 Litter size, 56 da	Duroc	13 K
62 56-112 da	Duroc	51 A	126 Litter size, 56 da	Duroc	18 K
63 56-112 da	Duroc	28 A	127 Litter size, 56 da	Composite	32 D
64 56-112 da	Crosses	35 A	128 Percent live pigs, 56 da	Composite	40 D
65 56-112 da	Not stated	28 A	129 Litter size, 56-70 da	Composite	17 K

/1/ Estimates of heritability are based on the indicated methods: A = paternal half sib correlation, B = maternal half sib correlation, C = paternal and maternal half sib correlations, D = intra-sire regression of progeny on dam, E = regression of progeny on mean of parents, F = correlation between progeny averages of sire and of son, G = regression of progeny on mean of parental full sibs, H = daughter-dam correlation, I = correlation between full sibs, J = line differences due to selection, K = repeatability of sow's own performance, L = variance between strains, M = regression of variance on genetic relationship between pigs, N = average of two methods, O = average of three methods, P = method not specified.

88. HERITABILITY ESTIMATES: FARM ANIMALS (Concluded)

Values are from the best available information; however, the inadequacies of heritability estimates should be remembered in using this table. Values in parentheses, unless otherwise noted, are estimate "d" of the 95% range (cf Introduction).

Part IV: SWINE (Concluded)

Characteristic	Breed	Estimate of Heritability ¹	Characteristic	Breed	Estimate of Heritability ¹
130 Litter size, 63 da	Duroc	-3 D	180 Thickness of shoulder fat	Yorkshire	42 A
131 Litter size, 70 da	Chester White	20 K	181 Thickness of shoulder fat	Yorkshire	49 C
132 Litter size, 154 da	Not stated	9 D	182 Thickness of loin fat	Yorkshire	48 A
133 Litter size, 154 da	P.C. and Landrace	-15 D	183 Thickness of loin fat	Yorkshire	59 C
134 Litter size, 168 da	Duroc	42 D	184 Thickness of belly	Swedish Landrace	39 A
135 Litter size, 168 da	Duroc	32 K	185 Thickness of belly	Danish Landrace	62 A
136 Litter size, 180 da	Duroc	-12 D	186 Thickness of belly	Danish Landrace	44 B
137 Litter weight at birth	Composite	36 D	187 Thickness of belly	Danish Landrace	47 F
138 Litter weight, 21 da	Swiss Land. and York.	12 K	188 Thickness of belly	Danish Landrace	46 O
139 Litter weight, 56 da	Composite	7 D	189 Length of carcass	Yorkshire	40 A
140 Litter weight, 56 da	Duroc	21 D	190 Length of carcass	Yorkshire	60 C
141 Litter weight, 56 da	Duroc	53 K	191 Length of carcass	Yorkshire	42 G
142 Litter weight, 56 da	Not stated	2 D	192 Length of carcass	Composite	48 P
143 Litter weight at weaning	Duroc	14 K	193 Length of carcass	P.C. and Landrace	73 A
144 Litter weight at weaning	Duroc	0 K	194 Length of carcass	Swedish Landrace	61 A
145 Litter weight, 60 da	Composite	18 K	195 Length of carcass	Danish Landrace	78 A
146 Litter weight, 154 da	Not stated	11 D	196 Length of carcass	Danish Landrace	81 B
147 Litter weight, 168 da	Duroc	2 D	197 Length of carcass	Danish Landrace	35 F
148 Litter weight, 168 da	Duroc	34 K	198 Length of carcass	Danish Landrace	54 O
149 Productivity index	Poland China	16 D	199 Length of hind leg	Duroc	23 A
150 Length of gestation	P.C. and Landrace	21 I	200 Length of hind leg	Composite	73 P
151 Feed economy	P.C. and Landrace	57 A	201 Length of hind leg	P.C. and Landrace	58 A
152 Feed economy	Duroc	26 E	202 Per cent lean cuts	P.C. and Landrace	29 A
153 Feed economy	Duroc	24 J	203 Per cent lean cuts	Composite	15 P
154 Feed economy	Yorkshire	30 A	204 Per cent fat cuts	P.C. and Landrace	52 A
155 Feed economy	Yorkshire	57 C	205 Per cent fat cuts	Composite	69 P
156 Feed economy	Composite	26 P	206 Per cent ham	Yorkshire	51 A
157 Feed economy	Danish Landrace	29 A ²	207 Per cent ham	Yorkshire	65 C
158 Feed economy	Danish Landrace	12 B ²	208 Per cent shoulder	Yorkshire	38 A
159 Feed economy	Danish Landrace	-10 F ²	209 Per cent shoulder	Yorkshire	56 C
160 Feed economy	Danish Landrace	8 O ²	210 Per cent Wiltshire sides	Danish Landrace	40 A
161 Feed economy	Swedish Landrace	12 A	211 Per cent Wiltshire sides	Danish Landrace	32 B
162 Feed economy	Swedish Landrace	23 A	212 Per cent Wiltshire sides	Danish Landrace	0 F
163 Market score	Duroc	33 N	213 Per cent Wiltshire sides	Danish Landrace	20 O
164 Market score	Poland China	10 D	214 Size of ham	Swedish Landrace	61 A
165 Age at slaughter	Swedish Landrace	57 A	215 Ham circumference	Duroc	17 A
166 Age at 200 lb weight	Yorkshire	55 A	216 Loin area	Yorkshire	66 A
167 Age at 200 lb weight Carcass	Yorkshire	85 C	217 Loin area	Yorkshire	79 C
168 Dressing per cent	P.C. and Landrace	38 A	218 Loin area	Yorkshire	16 G
169 Thickness of backfat	P.C. and Landrace	54 A	219 Carcass score	Yorkshire	35 G
170 Thickness of backfat	Duroc	12 A	220 Carcass score	Yorkshire	35 A
171 Thickness of backfat	Composite	40 P	221 Carcass score	Yorkshire	49 C
172 Thickness of backfat	Landrace Danish	80 A	222 Belly score	Yorkshire	14 A
173 Thickness of backfat	Danish Landrace	55 B	223 Firmness of fat score	Swedish Landrace	35 A
174 Thickness of backfat	Danish Landrace	37 F	224 Conformation score	Poland China	20 D
175 Thickness of backfat	Danish Landrace	47 O	225 Type score within strains	Poland China	38 A
176 Thickness of backfat	Swedish Landrace	54 A	226 Type score between strains	Poland China	92 L
177 Thickness of backfat	Yorkshire	37 G	227 Number of vertebrae	Composite	74 E
178 Thickness of backfat	Yorkshire	38 A	228 Scrotal hernia	P.C. and Landrace	15 A
179 Thickness of backfat	Yorkshire	53 C	229 Amount of spotting	Beltsville No. 1	76 O

/1/ Estimates of heritability are based on the indicated methods: A = paternal half sib correlation, B = maternal half sib correlation, C = paternal and maternal half sib correlations, D = intra-sire regression of progeny on dam, E = regression of progeny on mean of parents, F = correlation between progeny averages of sire and of son, G = regression of progeny on mean of parental full sibs, H = daughter-dam correlation, I = correlation between full sibs, J = line differences due to selection, K = repeatability of sow's own performance, L = variance between strains, M = regression of variance on genetic relationship between pigs, N = average of two methods, O = average of three methods, P = method not specified.

/2/ To be multiplied by $(1 + 3r_{00})$ where r_{00} is the correlation between litter mates.

89. GENETIC SEGREGATIONS AT 1% AND 5% PROBABILITY LEVELS

Values are given for the number of offspring required in order to obtain at least one desired individual among different genetic segregations at 1% and 5% probability levels. Numbers underlined indicate that corresponding calculated numbers are between 0.01 and 0.49 greater than the number entered.

Ratio of Undesired to Desired Type		Type of Segregation	Number ¹ of Required Offspring		Remarks
			Probability Level		
			1%	5%	
F ₂ Segregation					
1	2:1	Monohybrid, homozygous lethal	12	7	General method for calculating number (n) of required individuals at desired probability levels for all Mendelian ratios: $p = \left(\frac{e}{f}\right)^n$ p = probability level desired e = the multiple dominant term of the numerator of a Mendelian fraction f = the common denominator of all the terms of the Mendelian fraction n = the number of required individuals needed to assure the desired probability level Example: How many individuals in a 15:1 Mendelian ratio are required to show at 5% probability that no double recessive is expected? p = 0.05 e = 15 f = 16 n = ? Solving by logarithms: n(log 15 - log 16) = log 0.05 Answer: n = 46.4 Note: Rule of thumb method for estimating any value of n is: at 5% probability use three times the Mendelian denominator; at 1% probability use five times the Mendelian denominator.
2	3:1	Any (normal) monohybrid	16	10	
3	15:1	Any dihybrid	71	46	
4	63:1	Any trihybrid	292	190	
5	255:1	Any tetrahybrid	1177	765	
Backcross (Testcross) Segregations					
6	1:1	Any monohybrid	7	4	
7	3:1	Any dihybrid	16	10	
8	7:1	Any trihybrid	35	22	
9	15:1	Any tetrahybrid	71	46	
10	31:1	Any pentahybrid	145	94	
Genotypic Segregations					
11	2:1	Any class of 3, e.g., 9:3:3:1	12	7	
12	5:1	Any class of 6, e.g., 9:6:1	25	16	
13	6:1	Any class of 7, e.g., 9:7 or 7:1	30	19	
14	8:1	Any class of 9, e.g., 9:3:3:1	39	25	
15	11:1	Any class of 12, e.g., 12:3:1	53	34	
16	14:1	Any class of 15, e.g., 15:1	67	43	
17	26:1	Any class of 27, e.g., 27:37	122	79	
18	36:1	Any class of 37, e.g., 27:37	168	109	
19	62:1	Any class of 63, e.g., 63:1	288	187	
20	80:1	Any class of 81, e.g., 81:175	371	241	

/1/ Values are calculated from formula, $n = k(r + \frac{1}{2})$, where k equals 4.61 and 3.00 for the 1% and 5% probability levels, respectively; r equals the ratio between the undesired and desired types.

90. SIGNIFICANT LEVELS OF t, F, AND χ^2 In each cell upper value represents 5% level, lower value 1% level.

		Degrees of freedom for greater mean square ¹												
		1	2	3	4	5	6	8	10	12	15	20	50	
Degrees of freedom for lesser mean square	t	F												
1	12.7 63.7	161 4052	200 4999	216 5403	225 5625	230 5764	234 5859	239 5981	242 6056	244 6106	246 6156	248 6208	252 6302	
2	4.3 9.9	18.5 98.5	19.0 99.0	19.2 99.2	19.2 99.2	19.3 99.3	19.3 99.3	19.4 99.4	19.4 99.4	19.4 99.4	19.4 99.4	19.4 99.4	19.5 99.5	
3	3.2 5.8	10.1 34.1	9.6 30.8	9.3 29.5	9.1 28.7	9.0 28.2	8.9 27.9	8.8 27.5	8.8 27.2	8.7 27.0	8.7 26.9	8.7 26.7	8.6 26.4	
4	2.8 4.6	7.7 21.2	6.9 18.0	6.6 16.7	6.4 16.0	6.3 15.5	6.2 15.2	6.0 14.8	6.0 14.5	5.9 14.4	5.9 14.2	5.8 14.0	5.7 13.7	
5	2.6 4.0	6.6 16.3	5.8 13.3	5.4 12.1	5.2 11.4	5.0 11.0	5.0 10.7	4.8 10.3	4.7 10.0	4.7 9.9	4.6 9.7	4.6 9.6	4.4 9.2	
6	2.4 3.7	6.0 13.7	5.1 10.9	4.8 9.8	4.5 9.2	4.4 8.8	4.3 8.5	4.2 8.1	4.1 7.9	4.0 7.7	3.9 7.6	3.9 7.4	3.8 7.1	
8	2.3 3.4	5.3 11.3	4.5 8.6	4.1 7.6	3.8 7.0	3.7 6.6	3.6 6.4	3.4 6.0	3.3 5.8	3.3 5.7	3.2 5.5	3.2 5.4	3.0 5.1	
10	2.2 3.2	5.0 10.0	4.1 7.6	3.7 6.6	3.5 6.0	3.3 5.6	3.2 5.4	3.1 5.1	3.0 4.8	2.9 4.7	2.8 4.6	2.8 4.4	2.6 4.1	
12	2.2 3.1	4.8 9.3	3.9 6.9	3.5 6.0	3.3 5.4	3.1 5.1	3.0 4.8	2.8 4.5	2.8 4.3	2.7 4.2	2.6 4.0	2.5 3.9	2.4 3.6	
15	2.1 2.9	4.5 8.7	3.7 6.4	3.3 5.4	3.1 4.9	2.9 4.6	2.8 4.3	2.6 4.0	2.6 3.8	2.5 3.7	2.4 3.5	2.3 3.4	2.2 3.1	
20	2.1 2.8	4.4 8.1	3.5 5.8	3.1 4.9	2.9 4.4	2.7 4.1	2.6 3.9	2.4 3.6	2.4 3.4	2.3 3.2	2.2 3.1	2.1 2.9	2.0 2.6	
50	2.0 2.7	4.0 7.2	3.2 5.1	2.8 4.2	2.6 3.7	2.4 3.4	2.3 3.2	2.1 2.9	2.0 2.7	2.0 2.6	1.9 2.4	1.8 2.3	1.6 1.9	
100	2.0 2.6	3.9 6.9	3.1 4.8	2.7 4.0	2.5 3.5	2.3 3.2	2.2 3.0	2.0 2.7	1.9 2.5	1.8 2.4	1.8 2.2	1.7 2.1	1.5 1.7	
∞	1.96 2.58	3.8 6.6	3.0 4.6	2.6 3.8	2.4 3.3	2.2 3.0	2.1 2.8	1.9 2.5	1.8 2.3	1.8 2.2	1.7 2.0	1.6 1.9	1.4 1.5	
	χ ² =	3.8 6.6	6.0 9.2	7.8 11.3	9.5 13.3	11.1 15.1	12.6 16.8	15.5 20.1	18.3 23.2	21.0 26.2	25.0 30.6	31.4 37.6	67.5 76.0	

/1/ With only one degree of freedom for greater mean square, $F = t^2$; and chi-square for n d.f. is equal to $n \times F$, for n and ∞ d.f.

91. BREEDING HABITS: MAMMALS

If the estrous cycle occurs typically in a species as an isolated event during the breeding season, the species is monestrous, (Me). If the cycles occur in series, continuously, or seasonally, the species is polyestrous, (Pe). If a female mates with only one male during its lifetime, the female is monogamous, (Mo); if it mates with a different male each breeding season it is polygamous, (Po); and if it mates with 2 or more different males during any one breeding season it is promiscuous, (Pr). Values in parentheses are ranges, estimate "d" of the 95% range (cf Introduction).

Species	Age at Puberty	Breeding Season	Sexual Cycle		Gestation Period, da	Litter		Mating Habits
			Type	Duration, da		Size	No./yr	
1 Man (<i>Homo sapiens</i>)	(12-15.4) yr	All yr	Pe	(27-28)	267 ¹	12, 3		
2 Antelope (<i>Hippotragus niger</i>)		All yr			(270-281)			
3 Ape (<i>Macaca sylvanus</i>)			Pe	(27-33)	210			
4 Armadillo (<i>Dasypus novemcinctus</i>)	1 yr	Summer	Me		(150-240)	4	1	
5 Ass (<i>Equus asinus</i>)	1 yr	Mar-Aug	Pe	22	365(340-385)	1		
6 Baboon (<i>Papio porcarius</i>)	4 yr	All yr	Pe	(29-42)	210	1		
7 Badger (<i>Taxidea taxus</i>)		Aug-Sept	Me		(183-265)	3(1-7)		
8 Bat (<i>Eptesicus fuscus</i>)		Fall	Me ⁴	150	35	2(1-4)	1-3	Pr
9 Bat, vampire (<i>Desmodus rotundus</i>)		All yr	Pe	5+ mo		1	1+	Po
10 Bear (<i>Ursus horribilis</i>)	(2-3) yr	June-July	Me		208(180-225)	2(1-4)		Mo
11 Beaver (<i>Castor canadensis</i>)	2 yr	Jan-Feb			120(65-128)	4(1-6)		
12 Bobcat (<i>Lynx rufus</i>)		Late Feb			50	3(1-4)		
13 Buffalo (<i>Bison bison</i>)	3 yr	All yr ⁵	Pe	21	275(270-285)	1(1-2)	1	Po
14 Camel (<i>Camelus spp</i>)		All yr	Pe	(10-20)	(315-410)	1		
15 Cat (<i>Felis catus</i>)	(6-15) mo	Feb-July	Pe ^{6, 7}	(15-28)	63(52-69)	4		Pr
16 Cattle (<i>Bos taurus</i>)	(6-14) mo	All yr	Pe	(14-23)	281(210-335)	1	1	Po, Pr
17 Chinchilla (<i>Chinchilla laniger</i>)	4 mo	All yr ⁸	Pe	28	(105-115)		(1-8)	
18 Chimpanzee (<i>Pan troglodytes</i>)	(8-9) yr	All yr	Pe	(34-35)	237(216-261)	1 ³		
19 Chipmunk (<i>Tamias striatus</i>)	(2.5-3) mo	Mar-July	Pe		31	(3-6)	2	
20 Deer (<i>Cervus elaphus</i>)	♂ 3.5; ♀ 2.5 yr	Sept-Oct	Pe		234(225-246)	13		Po, Pr
21 Dog (<i>Canis familiaris</i>)	(6-8) mo	Spring-fall	Me	9	63(53-71)	7(1-22) ⁹		Pr
22 Eland (<i>Taurotragus oryx</i>)		All yr	Pe	21	260(255-270)	1		
23 Elephant (<i>Elephas maximus</i>)	(8-16) yr		Pe	3-4 ¹⁰	624(510-720)	1		
24 Elk (<i>Alces alces</i>)		Sept-Oct	Me	14	(240-250)	1 ³		Po
25 Ferret (<i>Mustela putorius</i>)		Mar-Aug	Pe ⁶		(42-45)	8.5	(5-13)	
26 Fox (<i>Vulpes fulva</i>)	10 mo	Dec-Mar ¹¹	Me	(2-4) ¹²	52(49-56)	(4-9)		Po
27 Gibbon (<i>Hylobates lar</i>)	8-10 yr	All yr	Pe	(29-30)	210	1		
28 Giraffe (<i>Giraffa camelopardalis</i>)		July-Sept	Pe		(400-480)	1		
29 Gnu (<i>Connochaetes taurinus</i>)	♀ 2 yr	June	Pe		(240-270)			
30 Goat (<i>Capra hircus</i>)	8 mo	Sept-winter	Pe ⁷	21	148(135-160)	(1-5)		Pr
31 Gopher (<i>Geomys brevicauda</i>)	3 mo	Feb-Aug	Pe		(40-50)	3(1-9)	1-3	
32 Guinea pig (<i>Cavia porcellus</i>)	(55-70) da	All yr	Pe	16	68(58-75)	3(1-8)		
33 Hamster (<i>Mesocricetus auratus</i>)	(5-8) wk	All yr	Pe	4	16(15-18)	(1-12)	3	
34 Hare (<i>Lepus americanus</i>)	1 yr	Mar-Aug	Pe		30(30-38)	3(1-7)	1	Pr
35 Hedgehog (<i>Erinaceus europaeus</i>)	2nd yr	Mar-Sept	Me		(35-49)	5(3-7)	1	
36 Hippopotamus (<i>Hippopotamus amphibius</i>)		All yr	Pe	30	231(210-250)	1		
37 Horse (<i>Equus caballus</i>)	1 yr	All yr ¹³	Pe ⁷	(10-37)	336(264-420)	1		
38 Hyena (<i>Crocuta crocuta</i>)		All yr	Pe	14	(91-110)	1		
39 Jaguar (<i>Panthera onca</i>)		Sept-Oct			(93-110)	(2-4)		
40 Kangaroo (<i>Macropus rufus</i>)		Once a yr			(38-40)	1		
41 Leopard (<i>Panthera pardus</i>)		All yr			(92-105)	3(1-4)		
42 Lion (<i>P. leo</i>)	2 yr	All yr	Pe	21	(105-113)	(1-6)		
43 Lynx (<i>Lynx canadensis</i>)		Early Mar			60	(1-5)		
44 Marmoset (<i>Hapale jacchus</i>)	♀ 14 mo				146(140-150)	2(1-3)		
45 Marten (<i>Martes foina</i>)	2 yr	July-Aug	Me		(255-285)	(3-5)		
46 Monkey (<i>Macaca mulatta</i>)	3 yr	All yr ¹⁴	Pe	28	164(155-180)	1		
47 Mouse (<i>Mus musculus</i>)	35 da	All yr	Pe	4	19(19-31)	6(1-12)	(4-6)	
48 Muskrat (<i>Ondatra zibethica</i>)	1 yr	Apr-Oct	Pe		30(19-42)	7(1-11)	2	Mo, Pr
49 Nutria (<i>Myocaster coypus</i>)	8 mo	All yr	Pe	(24-29)	(120-150)	10		
50 Otter (<i>Lutra canadensis</i>)	1 yr	Feb	Me		60	(1-4)		
51 Panther (<i>Felis concolor</i>)		All yr ¹⁵			(90-93)	3	(1-2)	
52 Swine (<i>Sus scrofa</i>)	7(5-8) mo	All yr	Pe	21	114(101-130)	9(6-15) ⁹		Po
53 Platypus (<i>Ornithorhynchus paradoxus</i>)	(1-2) yr	July-Oct	Me	60		2		
54 Porcupine (<i>Erethizon dorsatus</i>)	3rd yr	Nov-Dec	Me		112	1(1-4)		
55 Rabbit (<i>Oryctolagus cuniculus</i>)	(5.5-8.5) mo	All yr	Pe ⁶		31(30-35)	8(1-13) ⁹		
56 Raccoon (<i>Procyon lotor</i>)	1 yr	Jan-June	Pe		63(60-73)	4(1-6)		
57 Rat (<i>Rattus norvegicus</i>)	(37-67) da	All yr ¹⁶	Pe	4-5	21(21-30)	12(4-20)	2	Pr
58 Reindeer (<i>Rangifer tarandus</i>)	1.5 yr	Sept-Oct			230(210-246)	1 ³		
59 Rhinoceros (<i>Didemnoceros sumatrensis</i>)	20 yr	July-Oct	Me		210	1		
60 Sable (<i>Martes zibellina</i>)	2 yr	June-Aug	Pe	(9-12)	(270-285)	(1-4)		
61 Sea lion (<i>Zalophus californianus</i>)		June-July	Me		(348-365)	1		
62 Seal (<i>Arctocephalus pusillus</i>)	2 yr	Oct-Dec			(330-360)	2(1-2)		
63 Sheep (<i>Ovis aries</i>)	(7-8) mo	Fall ¹⁷	Pe	(16-21)	151(144-152)	(1-4) ⁹		Pr
64 Shrew (<i>Sorex araneus</i>)	2nd yr	Mar-Sept	Me		(35-49)	5(3-7)	1	
65 Skunk (<i>Mephitis mephitis</i>)		Mar		(9-10)	62	3-8		
66 Squirrel (<i>Sciurus carolinensis</i>)	(1-2) yr	Dec-Aug ¹⁸			44	4(1-6)	(1-2)	Pr
67 Tapir (<i>Tapirus terrestris</i>)		Seasonal ¹⁸			397(392-405)			
68 Tiger (<i>Panthera tigris</i>)	1.5 yr	All yr			(105-112)	3(1-6)		
69 Vole (<i>Microtus agrestis</i>)	♂ 6-8; ♀ 3 wk	Feb-Oct	Pe		21(21-29)	4		Pr
70 Walrus (<i>Odobenus rosmarus</i>)	4-5 yr	Apr-July			365(330-370)			
71 Wapiti (<i>Cervus canadensis</i>)	3 yr	All yr ¹⁹	Pe	21	255(249-262)	1 ³	1	Po
72 Waterbuck (<i>Kobus ellipsiprymnus</i>)		May-July	Pe	21	240	1		
73 Whale (<i>Balaenoptera borealis</i>)	2 yr	May-Aug	Pe		360	1		
74 Wolf (<i>Canis lupus</i>)	2 yr	Dec-Apr			63	(3-9)	2	
75 Woodchuck (<i>Marmota monax</i>)	1 yr	Mar-Apr			28	4		
76 Woodrat (<i>Neotoma micropus</i>)		Apr-Dec	Pe		33	2(2-3)		
77 Zebra (<i>Equus quagga</i>)		Mar-Nov			(340-365)	1		

/1/ 274-280 days from 1st day of last menses, 267 days from ovulation. /2/ Twins in 83 births; triplets in 6,889 births; quadruplets in 571,787 births, etc. /3/ Usually. /4/ Ovulation in spring. /5/ Peak, July-Sept. /6/ Induced ovulation. /7/ Seasonally. /8/ Peak, late fall-winter. /9/ Differs with strain or breed. /10/ In captivity. /11/ Peak, late Jan-Feb. /12/ Period of sexual receptivity. /13/ Mainly spring-summer. /14/ Except summer; Oct-Jan, fertile months. /15/ Peak, Jan. /16/ Except winter. /17/ Few breeds all year. /18/ Prior to rainy season. /19/ Peak, Sept-Oct.

92. INCUBATION, NESTLING, AND PARENTAL ATTENTIVENESS: BIRDS

The amount of time or activity engaged in by each sex (as indicated in column headings) in nest building, incubation, or feeding and care, is represented by symbols ranging from 0 (no time or activity) to ++++ (100% of activity).

Order, Family	Common Name	Nest Building		Incubation				Feeding and Care of Young				
		Male	Female	Duration da	Male	Female	Attentive Periods ¹	Male Feeds Female	Nestling Period ² da	Male	Female	Trips per Hour ³
1	Struthioniformes											
	Struthionidae											
	Rheiformes											
2	Rheidae											
	Rheas			35-42	++++	0		0	0	++++	0	
3	Casuariiformes											
	Dromiceidae											
	Emus, cassowaries			58-61	++++	0	Continuous	0	0	++++	0	
4	Apterygiformes											
	Apterygidae											
	Kiwis	++	++	75	++++	0	Up to 7 da	0	6	++++	0	
5	Tinamiformes											
	Tinamidae											
	Tinamous			21	++++	0		0	0	++++	0	
6	Sphenisciformes											
	Spheniscidae											
	Penguins	++	++	38-56	++	++	1-5+ da	0	56-112	++	++	1-2/da
7	Gaviiformes											
	Gaviidae											
	Loons			28-30	++	++		0	0	++	++	
8	Colymbiformes											
	Colymbidae											
	Grebes	++	++	21-27	++	++	0.5-5 hr	0	0	++	++	
9	Procellariiformes											
	Diomedidae											
	Albatrosses	++	++	63-80	++	++	5.3-21.8 da	0	150-251	++	++	2-5/wk
10	Procellariidae											
	Fulmars, shearwaters	++	++	51-58	++	++	1-7 da	0	49-95	++	++	0.5-2/da
11	Hydrobatidae											
	Storm petrels	++	++	38-50	++	++	1-5 da	0	56	++	++	1/da
12	Pelecanoididae											
	Diving petrels	++	++	56	++	++	1 da	0	54	++	++	1-2/da
	Pelecaniformes											
13	Phaethontidae											
	Tropic-birds			28	++	++		+	62	++	++	2-3/da
14	Pelecanidae											
	Pelicans			28-42	++	++		0	14-35	++	++	3+/da
15	Sulidae											
	Boobies	++	++	42-45	++	++	1 da	0	45+	++	++	1+/da
16	Phalacrocoracidae											
	Cormorants	++	++	24-25	++	++	1-3 hr	0	35-42	++	++	1
17	Anhingidae											
	Anhingas				++	++				++	++	
18	Fregatidae											
	Man-o'-war birds	++	++		++	++				++	++	
	Ciconiiformes											
19	Ardeidae											
	Heron, bitterns	++	++	18-28	++	++	1-6 hr	0	10-52	++	++	0.5-3
20	Scopidae											
	Hammerheads	++	++	21	++	++			42	++	++	
21	Ciconiidae											
	Storks	++	++	30-38	++	++	1-4.5 hr	0	63	++	++	5-11/da
22	Threskiornithidae											
	Ibises	++	++	21-24	++	++	6-18 hr	0	42+	++	++	12-20/da
23	Phoenicopteridae											
	Flamingos			30-32	++	++	12 hr		3-4	++	++	
	Anseriformes											
24	Anhimidae											
	Screamers	++	++	42	++	++	7-17 hr	0	0			
25	Anatidae											
	Swans, geese, ducks	+	+++	21-35	+	+++	4-23.7 hr	0	0	+	+++	
	Falconiformes											
26	Cathartidae											
	Vultures			39-56	++	++		0	56-70	++	++	
27	Accipitridae											
	Hawks	+	+++	28-56	+	+++	1-20 hr	+++	28-133	++	++	0.1-4
28	Falconidae											
	Falcons	+	+++	28-29	+	+++	3 hr	+++	25-35	++	++	0.3-5.8
	Galliformes											
29	Megapodidae											
	Megapodes	++++	0	57-70	0	0		0	0			
30	Cracidae											
	Chachalacas	++	++	22-24	0	++++		0	0			
31	Tetraonidae											
	Grouse, ptarmigans	0	++++	21-27	0	++++	6-11.5 hr	0	0	+	+++	
32	Phasianidae											
	Quail, pheasants	++	++	21-28	+	+++	7-23+ hr	0	0	++	++	
33	Meleagrididae											
	Turkeys	0	++++	28	0	++++	23-24 hr	0	0	0	++++	
34	Opisthocomidae											
	Hoatzins	++	++									
	Gruiformes											
35	Mesoenatidae											
	Monias				+++	+		0		+++	+	
36	Turnicidae											
	Bustard-quail	++	++	12-13	++++	0		0	0	++++	0	
37	Pedionomidae											
					++++	0		0	0	++++	0	
38	Gruidae											
	Cranes	++	++	29-32	++	++	44-165 min	0	0	++	++	
39	Rallidae											
	Rails	++	++	19-24	++	++	38 min	++	0-2	++	++	
40	Rhynchotidae											
	Kagus	++	++	36	++	++						
41	Eurypygidae											
	Sun-bitterns	++	++	27	++	++		0	21	++	++	
42	Otididae											
	Bustards			20-25	0	++++			0	0	++++	
	Charadriiformes											
43	Jacaniidae											
	Jacanas			23	++++	0				++++	0	
44	Rostratulidae											
	Painted snipes				+++	(?)						
45	Haematopodidae											
	Oyster-catchers			24-27	++	++	12 hr	0	0	++	++	
46	Charadriidae											
	Plovers	++	++	23-28	++	++	0.5-2.3 hr	0	0	++	++	
47	Scolopacidae											
	Sandpipers			18-29	++	++	11-15 hr	0	0	++	++	
48	Recurvirostridae											
	Avocets	++	++	23	++	++	10-66 min	0	0			
49	Phalaropodidae											
	Phalaropes	++++	0	20-21	+++	+		0	0	+++	+	
50	Burhinidae											
	Thick-knees			26-27	++	++		0	0			
51	Glareolidae											
	Pratincoles				+	+++						
52	Stercorariidae											
	Skuas, jaegers			23-26	++	++			0	++	++	
53	Laridae											
	Gulls, terns	++	++	20-34	++	++	0.5-24 hr	+	0-several	++	++	0.2-7
54	Rhynchopidae											
	Skimmers				0	++++		0	0	++	++	
55	Alcidae											
	Murres, puffins, guillemots	++	++	24-42	++	++	12 hr	+	2-49	++	++	
	Columbiformes											
56	Pteroclididae											
	Sand grouse			22-28	++	++	12 hr	0				
57	Raphidae											
	Solitaires			49	++	++						
58	Columbidae											
	Pigeons, doves	++	++	12-19	++	++	4-20 hr	0	10-35	++	++	0.2-1

/1/ Time bird sits on eggs at one sitting before leaving to feed and rest. /2/ Time from hatching until the birds leave the nest. /3/ Unless otherwise indicated.

92. INCUBATION, NESTLING, AND PARENTAL ATTENTIVENESS: BIRDS (Concluded)

The amount of time or activity engaged in by each sex (as indicated in column headings) in nest building, incubation, or feeding and care, is represented by symbols ranging from 0 (no time or activity) to ++++ (100% of activity).

Order, Family		Common Name	Nest Building		Incubation				Feeding and Care of Young				
			Male	Female	Duration da	Male	Female	Attentive Periods ¹	Male Feeds Female	Nestling Period ² da	Male	Female	Trips per Hour ³
59	Psittaciformes Psittacidae	Parrots	+	+++	17-31	+	+++	Continuous	++++	28-36	++	++	
60	Cuculiformes Cuculidae	Cuckoos	++	++	11-18	++	++	0.5-1.5 hr	0	6-22	++	++	2-12
61	Strigiformes Tytonidae	Barn owls			30-34	+	+++		+++	56-64+	++	++	1.4-2.0
62	Strigidae	Owls	++	++	27-35	+	+++	23.5 hr	+++	21-35	++	++	1-8
63	Caprimulgiformes Caprimulgidae	Goatsuckers	0	0	16-20	+	+++	1.4-14 hr	+	0	++	++	3.7
64	Apodiformes Apodidae	Swifts	++	++	17-21	++	++	32-75 min	+	20-42	++	++	0.7-2.5
65	Trochilidae	Hummingbirds	0	++++	16-17	0	++++	5-99 min	+	19-25	0	++++	1.1-3.3
66	Trogoniformes Trogonidae	Trogons	++	++	18-19	++	++	2-16 hr	0	16-30	++	++	2.0-2.4
67	Coraciiformes Alcedinidae	Kingfishers	++	++	21-23	++	++	1.7-24 hr	+	24-35	++	++	1.9-3.8
68	Momotidae	Motmots	+	+++	17-21	++	++	1-5 hr	0	28-30	++	++	4.0-4.8
69	Meropidae	Bee-eaters	++	++	22	++	++	15-30 min		30	++	++	
70	Coraciidae	Rollers			18-19	++	++			26-28	++	++	
71	Upupidae	Hoopoes			16	0	++++	11.5 hr	++++	29	++	++	1.9
72	Phoeniculidae	Wood hoopoes									++	++	3
73	Bucerotidae	Hornbills	++	++	28-40	0	++++	Continuous	++++	75	+++	+	1.6-2+
74	Piciformes Galbulidae	Jacamars	+	+++	19-22	++	++	145 min	+	20-26	++	++	
75	Bucconidae	Puffbirds	++	++		++	++	58 min	0				
76	Capitonidae	Barbets	++	++	13-15	++	++	37 min	+		++	++	
77	Ramphastidae	Toucans			16	++	++	38 min	0	43-45	++	++	3.4
78	Picidae	Woodpeckers	+++	+	11-18	+++	+	22-147 min	0	19-35	+++	+	1-30
79	Passeriformes Dendrocolaptidae	Wood hewers	++	++	15±	++	++	27 min	0	19	++	++	9.7
80	Furnariidae	Oven birds	++	++	15-20	++	++	22-97 min	0	13-29	++	++	2-4
81	Formicariidae	Antbirds	++	++	14-17	++	++	79-180 min	0	9-13	++	++	1.3-5.3
82	Cotingidae	Cotingas	+	+++	18-19	0	++++	12-37 min	0	19-25	++	++	
83	Pipridae	Manakins	0	++++	19-21	0	++++	111 min	0	13-15	0	++++	1.2
84	Tyrannidae	Tyrant flycatchers	+	+++	14-21	0	++++	9-57 min	+	12-24	+	+++	3.7-35.0
85	Menuridae	Lyrebirds	0	++++	28	0	++++			42	0	++++	
86	Alaudidae	Larks	0	++++	11-12	+	+++		+	9-12	++	++	5.9-8
87	Hirundinidae	Swallows	++	++	14-18	+	+++	6-33 min	+	18-28	++	++	4-40
88	Oriolidae	Old world orioles	+	+++	14-15	+	+++			14-15	++	++	
89	Corvidae	Crows	++	++	16-20	+	+++	35-94 min	+++	15-38	+	+++	1.7-4
90	Paradisidae	Birds of paradise	0	++++	14-18	+	+++	16-36+ min	0	18-31	+	+++	12.9
91	Paridae	Titmice	++	++	13-15	+	+++	10-38 min	++	14-21	++	++	3.6-34.5
92	Sittidae	Nuthatches	++	++	15	0	++++	31 min	++	22-24	++	++	11.9-18.4
93	Certhiidae	Creepers	+	+++	15	+	+++		+	15-20	++	++	
94	Chamaeidae	Wren-tits	++	++	15-16	++	++	47 min	0	15-16	++	++	8.8
95	Timalidae	Babbling thrushes	+	+++	21±	+	+++		+		+	+++	
96	Cinclidae	Dippers	+	+++	16	+	+++	31 min	+	19-24	+	+++	8.8-25.9
97	Troglodytidae	Wrens	++	++	14-19	0	++++	12-86 min	+	13-22	++	++	5.6-19.2
98	Mimidae	Thrashers, catbirds	+	+++	12-13	+	+++	20.8-	0	11-14	++	++	3.6-14.2
								22.7 min					
99	Turdidae	Thrushes	+	+++	12-14	+	+++	12-120 min	+	12-18	++	++	5.5-38.5
100	Sylviidae	Old world warblers	+	+++	12-15	+	+++	11-80 min	+	9-14	++	++	10-33
101	Regulidae	Kinglets	++	++	14-17	0	++++		0	18-20	++	++	17.5
102	Muscicapidae	Old world flycatchers	++	++	12-20	+	+++	15-87 min	++	10-20	++	++	6.2-33.6
103	Prunellidae	Accentors, hedge sparrows	+	+++	12-15	+	+++	19-30 min	+	13	++	++	5.1
104	Motacillidae	Pipits	+	+++	13-14	+	+++	19-48 min	+	10-15	+	+++	3.6-25
105	Bombacillidae	Waxwings	++	++	12	+	+++	37 min	+++	16	++	++	3.0
106	Ptilonotidae	Silky flycatchers	+++	+	15	++	++	9 min	+	18-19	+++	+	2.5-5.3
107	Artamidae	Wood-swallows	+++	+		+++	+		0		++	++	
108	Laniidae	Shrikes	++	++	16	+	+++	23 min	+++	15-21	++	++	
109	Prionopidae	Wood-shrikes	++	++		++	++	17-30 min			++	++	7-10.9
110	Sturnidae	Starlings	++	++	12	++	++		0	20-21	++	++	19-22
111	Meliphagidae	Honey-eaters	+	+++	13-18	+	+++	20 min	0	14-18	++	++	9
112	Nectariniidae	Sun birds	+	+++	12-13	+	+++				+	+++	20
113	Dicaeidae	Flower-peckers	+	+++		+	+++				++	++	
114	Zosteropidae	White-eyes	++	++	11-12	++	++		0	9-11	++	++	7
115	Vireonidae	Vireos	+	+++	13-14	+	+++	10-38 min	0	11-13	++	++	3.9-13.5
116	Coerebidae	Honey creepers	+	+++	12-14	0	++++	19-61 min	0	14-19	++	++	4.7-13.2
117	Parulidae	Wood warblers	+	+++	11-17	0	++++	23-110 min	+	8-14	++	++	1.6-27.4
118	Ploceidae	Weaver finches	+++	+	12-16	+	+++	14 min	0	13-19	+	+++	4-20
119	Icteridae	Blackbirds	0	++++	11-14	0	++++	9-30 min	+	9-34	+	+++	6.2-17.7
120	Thraupidae	Tanagers	+	+++	12-16	0	++++		++	10-24	++	++	
121	Fringillidae	Finches, sparrows	+	+++	11-14	+	+++	14.6- continuous	++	8-17	++	++	1.3-21.3

/1/ Time bird sits on eggs at one sitting before leaving to feed and rest. /2/ Time from hatching until the birds leave the nest. /3/ Unless otherwise indicated.

93. NESTING SUCCESS: SOME PRECOCIAL AND ALTRICIAL BIRDS

Precocial young are hatched covered with down and ready to leave the nest in a few hours. Altricial young are born blind and naked, and need parental brooding and feeding for some time; when they leave the nest they are covered with feathers and can walk or hop and are soon able to fly. In some respects fledging of altricials corresponds to hatching of precocials.

Part I: SUCCESS OF OPEN NESTS: ALTRICIAL SPECIES

Data adapted by Nice, M. M.

Species	Nests			Eggs			
	Total	Successful	%	Total	Hatched	Fledged	%
1 Mourning dove (<i>Zenaidura macroura</i>)	249	130	52.8	500		213	42.6
2	592	309	52.2				
3	4273	2043	47.9	8018	4379	3734	46.6
4	235	122	52.0				
5	204	142	69.6	398	310	274	68.8
6 Horned lark (<i>Otocoris alpestris</i>)	30	18	60.0	102	79	46	45.1
7 American robin (<i>Turdus migratorius</i>)	136	78	57.3	259	157	131	54.4
8	64	49	76.6				
9	176	86	48.8	548	316	246	44.9
10 Whinchat (<i>Saxicola rubetra</i>)	129	57	44.4				
11 Cedar waxwing (<i>Bombycilla cedrorum</i>)	60	46	76.7	245	189	171	69.8
12 Redwing (<i>Agelaius phoeniceus</i>)	67			214	156	105	49.1
13	356			1140	823	675	59.2
14 Yellow-headed blackbird (<i>Xanthocephalus xanthocephalus</i>)	128			443	314	99	22.4
15 Brewer's blackbird (<i>Euphagus cyanocephalus</i>)	107	53	49.5	521	327	205	39.3
16 Bronzed grackle (<i>Quiscalus versicolor</i>)	62	34	54.8	288	209	135	46.9
17 Goldfinch (<i>Spinus tristis</i>)	35	21	60.0	161	113	80	49.7
18	239			696	455	338	48.6
19 McCown's longspur (<i>Rhynophanus mccowni</i>)	45	27	60.0	153	92	71	46.4
20 Corn bunting (<i>Emberiza calandra</i>)	54			207		126	60.9
21	53	40	76.7	204		144	70.6
22 Chipping sparrow (<i>Spizella passerina</i>)	88	55	62.5	277	185	170	61.4
23 Field sparrow (<i>S. pusilla</i>)	593	226	38.1	1738	888	620	35.7
24 Song sparrow (<i>Melospiza melodia</i>)	147	77	52.4	585	389	243	41.5
25	76	30	39.5	321	147	80	24.9
26 Seven species	43	18	41.9				
27 Eight species	240	99	41.2				
28 Twenty-five species	246	101	41.0				
29 Ten species	30	20	66.6	145	93	70	48.3
30 Species (number not specified)	156			687	420	300	43.7
31 Eleven species	71			265	160	124	46.7
32 Six species	113			428	295	248	55.6
33 Eleven species				2151	1299	1010	46.9
34 Six species	121	57	47.0	421	257	170	40.4
Summary ¹							
35 25 Studies, nest success	8034	3938	49.0				
36 24 Studies, hatching success of eggs laid				20,204	12,052	59.7	
37 22 Studies, hatching success of passerine eggs				11,788	7,363	62.5	
38 27 Studies, fledging success of eggs laid				21,115		9,728	46.1

/1/ The frequency of the percentages of hatching success in the 24 studies is: 1, 40-49; 3, 50-59; 12, 60-69; 8, 70-79. The median is 64.7%, in contrast to the 59.7% average of the 20,204 eggs. It is clear that this figure is biased by the low success (54.6%) of the 8,018 mourning dove eggs. Mourning doves build notoriously frail nests. Omitting the two mourning dove studies, the hatching success of the 11,788 passerine (song birds) eggs is 62.5%. The frequency of the percentages of fledging success in the 27 studies is: 2, 20-29; 2, 30-39; 14, 40-49; 4, 50-59; 3, 60-69; 2, 70-79. The median is 46.9%, which corresponds closely to the 46.1% average for the 21,115 eggs.

Part II: HATCHING SUCCESS OF SOME PRECOCIAL SPECIES: GALLINACEOUS BIRDS

Data adapted from Hickey, J. J., "Recent Studies in Avian Biology," edited by Albert Wolfson, University of Illinois Press: Urbana, 1955.

Species	Place	Number of Nests	Per Cent Successful
1 Ring-necked pheasant (<i>Phasianus colchicus</i>)	Iowa	445	23
2	Pennsylvania	310	20
3	Ohio	563	58
4	Utah	149	36
5	Iowa	527	26
6 California quail (<i>Lophortyx californica</i>)	California	96	18
7 Bobwhite quail (<i>Colinus virginianus</i>)	Georgia, Florida	602	36
8	Texas	189	46
9 European partridge (<i>Perdix perdix</i>)	Michigan	143	32
10	Wisconsin	435	32
11 Summary: 10 studies on Phasianinae		3299	35.5
12 Willow ptarmigan (<i>Lagopus lagopus</i>)	Norway	125	63
13	Norway	107	80
14 Ruffed grouse (<i>Bonasa umbellus</i>)	New York	1431	61.4
15 Prairie chicken (<i>Tympanuchus cupido</i>)	Wisconsin	100	50
16 Sage grouse (<i>Centrocercus urophasianus</i>)	Utah	161	60
17	Colorado	238	35
18	Wyoming	134	34
19 Summary: 7 studies on Tetraoninae		2296	57.5
20 Total summary: 17 studies		5595	44.5

93. NESTING SUCCESS: SOME PRECOCIAL AND ALTRICIAL BIRDS (Concluded)

Precocial young are hatched covered with down and ready to leave the nest in a few hours. Altricial young are born blind and naked, and need parental brooding and feeding for some time; when they leave the nest they are covered with feathers and can walk or hop and are soon able to fly. In some respects fledging of altricials corresponds to hatching of precocials.

Part III: SUCCESS OF SOME HOLE-NESTING ALTRICIAL SPECIES

Data adapted from Allen, R. W., and Nice, M. M., American Midland Naturalist, 47:606-665, 1952.

Species	Years Observed	Nests	Eggs	Hatched		Fledged	
				Number	%	Number	%
1 Tree swallow (<i>Iridoprocne bicolor</i>)	9	219	1123	928	83.4	679	61.0
2	3	352	1759	1424	81.0	857	48.7
3	3	80	430	310	72.1	303	70.5
4	2	37	184	163	88.6	123	66.8
5	8	60	363	358	98.6	340	93.7
6 Pied flycatcher (<i>Muscicapa hypoleuca</i>)	8	221	1074			789	73.5
7 Black-capped chickadee (<i>Parus atricapillus</i>)	2	11	74			53	71.6
8 Great tit (<i>P. major</i>)	5	202	1936	1653	85.4	1416	75.1
9	19	5011	45,466			29,529	64.9
10	2	66	460	425	92.4	340	72.4
11	2	623	6012	4579	76.2	3938	65.5
12 Blue tit (<i>P. caeruleus</i>)	5	183	1887	1548	82.0	1453	77.0
13	2		247	185	75.0	168	68.0
14	4	37	286	187	65.0	128	44.7
15	2	46	413	366	88.6	327	79.2
16 Coal tit (<i>P. ater</i>)	1	18	161	153	95.0	131	81.4
17 House wren (<i>Troglodytes aedon</i>)	19	1056	6673	5576	82.3	5351	79.0
18	3	34	211	135	64.0	118	55.2
19	6		469			339	83.7
20	21	64	333	199	59.7	161	48.3
21 Bewick wren (<i>Thryomanes bewicki</i>)	15	21	129			79	56.8
22 Bluebird (<i>Sialia sialis</i>)	11	1401	6260	3943	63.0	2786	44.5
23	2	86	377	302	80.1	274	72.7
24	3	301	1290			839	65.0
25	9	67	272	213	78.3	172	63.2
26	20	50	203	131	64.5	127	62.5
27 Starling (<i>Sturnus vulgaris</i>)			10,557			7923	75.1
28	6		472			410	84.5
29 Prothonotary warbler (<i>Protonotaria citrea</i>)	11	121	413	159	38.5	106	25.7
30	2	36	163	100	61.3	100	61.3
31 House sparrow (<i>Passer domesticus</i>)	6		114			97	78.5
32 Five species	2		755			500	66.2
Summary							
33 22 Studies (7 species) on hatching success			30,276	23,537	77.7		
34 32 Studies (14 species) on fledging success			90,676			60,016	66.2

94. BREEDING HABITS: REPTILES

In many of the ovoviviparous forms there exists a type of placentation, verging in some cases on viviparity; however, to avoid confusion, the term viviparous is not used. All reptiles have internal fertilization. Values in parentheses are ranges, estimate "d" of the 95% range (cf Introduction).

Species	Sexual Maturity ¹ yr	Breeding Season ²	Manner of Birth	Gestation or Incubation Time ³	Broods ⁴	
					Size ⁵	No./yr
Crocodilia						
1 Alligator, American (<i>Alligator mississippiensis</i>)	5-10	Jan-Sept	Oviparous	56-66	29-88	1
Sauria						
2 Chameleon, false (<i>Anolis carolinensis</i>)	♂ 2; ♀ 1	Apr-Aug	Oviparous	6-7 wk	1	8-10
3 Gila monster (<i>Heloderma suspectum</i>)			Oviparous	30	5-13	1
4 Lizard, alligator (<i>Gerrhonotus multicarinatus</i>)		May	Oviparous	51-60	8-20	1
5 Lizard, collared-, western (<i>Crotaphytus collaris</i>)	<1-<3	May-June	Oviparous	8-13 wk	4-24	1
6 Lizard, night desert (<i>Xantusia vigilis</i>)	♀ 3	May-June	Ovoviviparous	3 mo	2(1-3)	1
7 Lizard, Pacific fence (<i>Sceloporus occidentalis</i>)	2	Mar-Apr	Oviparous	2 mo	9(6-13)	1
8 Lizard, sagebrush (<i>Sceloporus graciosus</i>)		Apr-May	Oviparous	62	2-7	1
9 Lizard, Texas horned (<i>Phrynosoma cornutum</i>)		Apr-May	Oviparous	39-47	23-37	1
10 Racerunner, common tessellated (<i>Cnemidophorus tigris</i>)		May-June	Oviparous	80	2-4	1-2
11 Skink, common five-lined (<i>Eumeces fasciatus</i>)	<2	May-June	Oviparous	4-9 wk	2-18	1
12 Slowworm (<i>Anguis fragilis</i>)	3-4	May-June	Ovoviviparous	3 mo	7-19	1
13 Uta, northern ground (<i>Uta stansburiana</i>)		Apr-May	Oviparous	61-67	2-4	1
Serpentes						
14 Bullsake (<i>Pituophis catenifer</i>)	<3	Apr-May	Oviparous	70(64-71)	3-19	1
15 Copperhead (<i>Ancistrodon contortrix</i>)	3-4	Apr-May	Ovoviviparous		142	2-10
16 Cottonmouth (<i>A. piscivorus</i>)		Mar-Apr; fall	Ovoviviparous	5 mo	3-15	1
17 Racer, western blue (<i>Coluber constrictor</i>)		May-June	Oviparous	1-2 mo	15-25	1
18 Racer, western striped (<i>Masticophis taeniatus</i>)	3	Apr-May	Oviparous			1
19 Rattlesnake, Gt. Basin (<i>Crotalus viridis</i>)	3-4	Apr-June	Ovoviviparous	4-5 mo	3-13	0.5
20 Snake, brown (<i>Storeria dekayi</i>)		Mar-Apr	Ovoviviparous	4 mo	14(13-24)	1
21 Snake, common garter (<i>Thamnophis sirtalis</i>)	2-3	Mar-May; fall	Ovoviviparous	87-116	28(6-51)	1-2
22 Snake, hog-nosed (<i>Heterodon platyrhinos</i>)		Apr-May	Oviparous		8-40	1
23 Snake, mud (<i>Farancia abacura</i>)		July	Oviparous	110 ⁶	22-104	1
24 Snake, Pacific rubber (<i>Charina bottae</i>)	2-3	June	Ovoviviparous		3-5	1
25 Snake, water (<i>Natrix erythrogaster</i>)		Apr-May	Ovoviviparous	120-150	8-27	1
Testudinata						
26 Terrapin, diamondback (<i>Malaclemys terrapin</i>)	5-6	Spring	Oviparous	3 mo	4-9	1-3
27 Tortoise, desert (<i>Gopherus agassizii</i>)	15-20	May	Oviparous	80-120	2-13	1
28 Turtle, Atlantic loggerhead (<i>Caretta caretta</i>)		Mar-July	Oviparous	31-65	120-130	2-3
29 Turtle, common box (<i>Terrapene carolina</i>)	3-5	Apr-May	Oviparous	88(70-114)	2-7	1
30 Turtle, common musk (<i>Sternotherus odoratus</i>)	♂ 2-3; ♀ 9-11	Apr-Oct	Oviparous	60-75	1-6	1
31 Turtle, common snapping (<i>Chelydra serpentina</i>)		Apr-Nov	Oviparous	81-90	25(8-80)	1-2

/1/ Males in some species mature before females. /2/ Varies with geographical distribution. /3/ Accepted average expressed in da; other values in wk or mo are approximations. /4/ Broods or clutch. Brood = young produced at one time; clutch = eggs laid at one time. /5/ Number of eggs or young. /6/ From one observation only.

95. BREEDING HABITS: AMPHIBIANS

Data should be considered with caution. Growth, particularly, may be modified greatly by changes in temperature, moisture, and light. Breeding data may vary when mating and egg laying are not concurrent but take place at the extremes of the cited season as, for example, with some salamanders.

Species	Breeding Season	Eggs or Young per Clutch	Fertilization	Place of Egg Development	Form at Hatching or Birth	Period of Growth to Sexual Maturity		
						Egg	Larva	Adult
Urodela								
1 Eel, congo (<i>Amphiuma tridactylum</i>) ¹	May-Nov	42-150	Internal ²	Terrestrial ³	Larva		2-3 yr	
2 Eel, mud (<i>Siren intermedia</i>) ¹		224-706		Aquatic	Larva		2 yr	
3 Hellbender (<i>Cryptobranchus alleganiensis</i>) ¹	Aug-Sept	300-450	External	Aquatic ⁴	Larva	64-84	540	5-6 yr
4 Mudpuppy (<i>Necturus maculosus</i>) ¹	Sept-June	18-180	Internal ²	Aquatic ³	Larva	38-63		5 yr
5 Newt, eastern (<i>Diemictylus viridescens</i>) ¹	Apr-June	200-375	Internal ⁵	Aquatic ⁶	Larva	20-35	80	2 yr
6 Salamander, Eschscholtz (<i>Ensatina eschscholtzi</i>) ¹	Oct-Apr	12-14	Internal ⁵	Terrestrial ³	Adult			
7 Salamander, European (<i>Salamandra salamandra</i>) ⁷	July	12-72	Internal ⁵	Terrestrial ³	Larva ⁹	90-150		4-5 yr
8 Salamander, four-toed (<i>Hemidactylium scutatum</i>) ¹	Apr-Oct	22-64	Internal ⁵	Terrestrial ³	Larva	38-60	148	2½ yr
9 Salamander, green (<i>Aneides aeneus</i>) ¹	May-June	10-26	Internal ⁵	Terrestrial ³	Adult	84-91		
10 Salamander, marbled (<i>Ambystoma opacum</i>) ¹	Sept-Jan	50-200	Internal ⁵	Terrestrial ³	Larva	30-180	180-240	410-510
11 Salamander, slimy (<i>Plethodon cinereus</i>) ¹	Oct-Dec	3-13	Internal ⁵	Terrestrial ³	Adult ¹⁰			2 yr
12 Salamander, spotted (<i>Ambystoma maculatum</i>) ¹	Mar-Apr	20-250				31-54	61-110	2 yr
13 Salamander, tiger (<i>A. tigrinum</i>) ¹	Jan-Mar	23-110	Internal ⁵	Aquatic ⁶	Larva	24-30	75-118	360
14 Salamander, two-toed (<i>Eurycea bislineata</i>) ¹	Jan-Apr	12-41	Internal ⁵	Aquatic ⁶	Larva	60-70	2-3 yr	
15 (<i>Hynobius chinensis</i>) ¹¹	May	35-70	External	Aquatic ⁴	Larva	60		
Anura								
16 Bullfrog (<i>Rana catesbeiana</i>) ¹	Feb-Aug	10,000-25,000	External	Aquatic ⁶	Embryo	4-5	2 yr	2-3 yr
17 Frog (<i>Zachaeus parvulus</i>) ¹²	July	30	External	Terrestrial ⁶	Adv. tadpole		17	
18 Frog, Chilean (<i>Rhinoderma darwini</i>) ¹²			External	Internal ¹³	Adult			
19 Frog, chirping (<i>Arthroleptella hewitti</i>) ¹⁴	October	36		Terrestrial	Adv. tadpole		10	
20 Frog, common (<i>Rana temporaria</i>) ⁷	Feb-Apr	1500-4000	External	Aquatic ⁶	Embryo	14-21	90-180	4-5 yr
21 Frog, cricket (<i>Acris gryllus</i>) ¹	All year	250	External	Aquatic ⁶	Embryo	4	50-90	2 yr
22 Frog, leopard (<i>Rana pipiens</i>) ¹	Feb-Dec	1200-1500	External	Aquatic ⁶	Embryo		60-90	1-2 yr
23 Frog, New Zealand (<i>Leiopelma hochstetteri</i>) ¹⁵	December	6-18	External	Terrestrial ¹⁶	Adult	30		
24 Toad, bell (<i>Ascaphus truei</i>) ¹	May-Sept	28-50	Internal	Aquatic ⁶	Embryo	30	365	
25 Toad, common tree (<i>Hyla versicolor</i>) ¹	Apr-July	1000-2000	External	Aquatic ⁶	Embryo	4-5	45-65	1-3 yr
26 Toad, Fowler's (<i>Bufo woodhousei</i>) ¹	Apr-Aug	8000	External	Aquatic ⁶	Embryo	2-4	40-60	
27 Toad, narrow mouth (<i>Microhyla carolinensis</i>) ¹	May-Sept	850	External	Aquatic ⁶	Embryo	2	20-70	2 yr
28 Toad, spadefoot (<i>Scaphiopus holbrookii</i>) ¹	Jan-Dec	100+	External	Aquatic ⁶	Embryo	0.5+	18-28	
29 Toad, Surinam (<i>Pipa pipa</i>) ¹²			External	Aquatic ¹⁷	Adult			
30 (<i>Discoglossus pictus</i>) ⁷	Jan-Oct	300-1000	External	Aquatic ⁶	Embryo	2-4	30-60	
31 (<i>Xenopus laevis</i>) ¹⁴	Sep-Oct	<100-1000	External	Aquatic ⁶	Embryo	3	35-300	♂ ½, ♀ 2 yr
Apoda								
32 Caecilian (<i>Typhlonectes compressicauda</i>) ¹²		6	Internal	Internal ^{3, 18}	Adult			

/1/ North America. /2/ From spermatophore deposited by male in female cloaca. /3/ Protected by female. /4/ Protected by male. /5/ From spermatophore laid by male and picked up by female. /6/ No parental protection. /7/ Europe. /8/ Carried by female. Viviparous form. /9/ Or adult. /10/ Gills at hatching or disappear before hatching. /11/ China. /12/ South America. /13/ In female vocal sac. /14/ Africa. /15/ New Zealand. /16/ Sex of protector not determined. /17/ On back of female. /18/ Viviparous form.

96. BREEDING HABITS: FISH

Data should be considered with caution because spawning activities vary widely with such factors as the species, area, and temperature of the water. Number of eggs may vary with size of female. A = salt water; B = pelagic or buoyant eggs; C = demersal eggs; D = fresh water; E = fluviatile; F = lacustrine; G = anadromous; H = brackish water.

Species	Spawning		Egg or Young	Number of Eggs	Type of Fertilization
	Season	Locale and Type			
1 Bass, largemouth (<i>Micropterus salmoides</i>)	Spring, summer	C D E F	Oviparous ¹	2,000-26,000	External
2 Bowfin (<i>Amia calva</i>)	Spring	C D E F	Oviparous ²	23,000-64,000	External
3 Bullhead, brown (<i>Ameiurus nebulosa</i>)	Spring	C D E F	Oviparous ³	2,000-10,000	External
4 Carp (<i>Cyprinus carpio</i>)	Spring, summer	C D F	Oviparous ²	500,000-2,000,000	External
5 Cod, Atlantic (<i>Gadus callarias</i>)	Winter, spring	A B	Oviparous ²	3,000,000-9,000,000	External
6 Dogfish, Atlantic spiny (<i>Squalus acanthias</i>)	All year	A	Ovoviviparous ²	2-11	Internal
7 Eel, American (<i>Anguilla rostrata</i>)	Winter	A B	Oviparous	5,000,000-20,000,000	External
8 Eel, Conger (<i>Conger oceanica</i>)	Summer	A B	Oviparous ²	3,000,000-7,900,000	External
9 Flounder, winter (<i>Pseudopleuronectes americanus</i>)	Winter, spring	A C	Oviparous	500,000-1,500,000	External
10 Gar, longnose (<i>Lepisosteus osseus</i>)	Spring	C D E F	Oviparous	36,500	External
11 Haddock (<i>Melanogrammus aeglefinus</i>)	Winter, spring	A B	Oviparous ²	169,000-1,840,000	External
12 Hagfish, Atlantic (<i>Myxine glutinosa</i>)	All year	A C	Oviparous ²	19-30	
13 Halibut, Atlantic (<i>Hippoglossus hippoglossus</i>)	Spring, summer	A B	Oviparous	2,183,000	External
14 Herring, Atlantic (<i>Clupea harengus</i>)	Spring, summer	A C	Oviparous ²	20,000-40,000	External
15 Lamprey, sea (<i>Petromyzon marinus</i>)	Spring	C D E G ⁴	Oviparous ²	236,000	External
16 Mackerel, Spanish (<i>Scomberomorus maculatus</i>)	Spring, summer	A B	Oviparous ²	20,000	External
17 Mummichog (<i>Fundulus heteroclitus</i>)	Spring, summer	C D E H	Oviparous ²	460	External
18 Pike, northern (<i>Esox lucius</i>)	Spring	C D E H	Oviparous ²	10,000-100,000	External
19 Pumpkinseed (<i>Lepomis gibbosus</i>)	Spring, summer	C D E F	Oviparous ¹	Several thousand	External
20 Ray, southern sting (<i>Dasyatis americana</i>)		A	Ovoviviparous ²	3-5	Internal
21 Salmon, Atlantic (<i>Salmo salar</i>)	Spring	C D E G ⁵	Oviparous ⁶	7000	External
22 Sea horse, northern (<i>Hippocampus hudsonius</i>)	Spring	A	Oviparous ¹	150	External
23 Shad (<i>Alosa sapidissima</i>)	Spring	C D E G	Oviparous ²	100,000-156,000	External
24 Shark, hammerhead (<i>Sphyrna zygaena</i>)	Summer	A	Viviparous ²	29-37	Internal
25 Shark, man-eater (<i>Carcharodon carcharias</i>)	Summer	A	Vivip. or Ovovi. ²	9	Internal
26 Skate, little (<i>Raja erinacea</i>)	All year	A C	Oviparous ²	6	Internal
27 Stickleback, three spine (<i>Gasterosteus aculeatus</i>)	Spring	D H	Oviparous ¹	100-150	External
28 Sturgeon, Atlantic (<i>Acipenser sturio</i>)	Spring, summer	C D E G	Oviparous ²	1,000,000-2,500,000	External
29 Trout, brown (<i>Salmo trutta</i>)	Autumn, winter	C D E ⁵	Oviparous ⁶	200-6000	External
30 Trout, rainbow (<i>S. gairdnerii</i>)	Spring, summer	C D E G ⁵	Oviparous ⁶	400-3000	External

/1/ Male guards nest or eggs. /2/ No parental care. /3/ Both parents guard nest or eggs. /4/ Dig shallow pits for nests on gravelly riffles. /5/ Clear, shallow, moving water on gravel nests or reeds. /6/ Eggs covered by gravel or sand.

97. BREEDING HABITS: AQUATIC INVERTEBRATES

Breeding habits of invertebrates vary with changes in location, temperature, light, and for marine forms, salinity. Asterisks indicate where data apply to specific locations providing the most complete information.

Species and Location	Sexual Maturity		Eggs or Young per Brood	Type Sexuality	Breeding Season	Ovum Type
	Age ¹	Size ² mm				
Xiphosura						
1 Crab, horseshoe (<i>Limulus polyphemus</i>), Delaware Bay area*	9-11 yr	♂ 178-258 ³	Few-1000	Dioecious ⁴	Apr-July	Oviparous
Crustacea						
2 Crab, blue (<i>Callinectes sapidus</i>), Chesapeake Bay area*	♂ ♀ 13 mo	♂ 135-215 ⁵	1,750,000	Dioecious ⁴	July-Aug	Ovigerous
3 Crayfish (<i>Orconectes immunis</i>), New York State area*	♂ ♀ 15 mo	♂ 40-60 ⁶	102(84-195)	Dioecious ⁴	June-Oct	Ovigerous
4 Cyclops (<i>Cyclops viridis</i>), Germany*	♂ 41-132 da ⁷	♀ 1.5-5 ⁸	75(20-160) ⁹	Dioecious ⁴	All year	Ovigerous
5 Lobster (<i>Homarus americanus</i>), Delaware-Newfoundland*	4-5 yr	♂ 17-60 ¹⁰	8500 ¹¹	Dioecious ⁴	July-Sept	Ovigerous
6 Waterflea (<i>Daphnia longispina</i>), northeastern U.S.A.*	♀ 75-86 hr	♂ 1.2; ♀ 1.9	28(4-35)	Dioecious ^{4, 12}	All year ¹³	Ovigerous
Mollusca						
7 Chiton, gray (<i>Ischnochiton magdalenensis</i>), Calif.-Mexico	2 yr	35-36	57,970	Dioecious		Oviparous
8 Clam, hard shell (<i>Venus mercenaria</i>), Baja California*	1-2 yr	5-7		Monocious ^{14, 15}	July-Aug	Oviparous
9 Clam, pismo (<i>Tivela stultorum</i>), Pacific area	5 yr	10-12	750,000	Monocious ^{14, 15}		Oviparous
10 Clam, razor (<i>Siliqua patula</i>), eastern Pacific area*	2-4.2 yr	10-14		Dioecious ¹⁴		Oviparous
11 Clam, soft shell (<i>Mya arenaria</i>), Arctic-N. Carolina; Pacific	1-2 yr			Dioecious ¹⁴	May-Aug	Oviparous
12 Drill, oyster (<i>Urosalpinx cinerea</i>), Delaware Bay area*	15-25 mo	15-24	300-960	Dioecious ¹⁴	Apr-Nov	Oviparous
13 Limpet (<i>Acmaea digitalis</i>), Alaska-Mexico				Dioecious ¹⁴		Oviparous
14 Mussel (<i>Mytilus edulis</i>), cosmopolitan	1-2 yr			Dioecious	May-Sept	Oviparous
15 Nudibranch, red (<i>Rostanga pulchra</i>), California			9-156	Monocious ^{14, 16}	Dec-Feb	Oviparous
16 Ormer (<i>Halotis tuberculata</i>), Channel Islands-Europe	3 yr	5	10,000	Dioecious ¹⁴	July-Sept	Oviparous
17 Oyster (<i>Crassostrea virginica</i>), Delaware Bay area	1 yr	25-50	1/2-1 million	Monocious ^{14, 15}	June-Aug	Oviparous
18 Periwinkle (<i>Littorina littorea</i>), North Atlantic-Florida			1-3	Dioecious ⁴		Oviparous
19 Scallop, bay (<i>Aequipecten irradians</i>), western Atlantic	12 mo	78		Monocious ¹⁴		Oviparous
20 Scallop, giant (<i>Placopecten magellanicus</i>), North Atlantic*	3-4 yr	50-70		Dioecious ¹⁴	June-Oct	Oviparous
21 Snail, burrowing (<i>Polynices duplicatus</i>), northern U.S.A.-Mexico	2 yr	>12		Dioecious ⁴	June-Aug	Oviparous
22 Snail, edible (<i>Helix pomatia</i>), Europe	33-39 mo		40-200	Monocious ^{14, 16}	May-July	Oviparous
23 Snail, pond (<i>Lymnaea stagnalis</i>), Wisconsin	4-14 mo	50-60	6,000	Monocious ^{14, 16}	July-Oct	Oviparous
24 Top-shell, great (<i>Trochus niloticus</i>), Indo-Pacific	2 yr	6-7		Dioecious ⁴		Oviparous
25 Whelk, channelled (<i>Busycon canaliculatum</i>), Cape Cod-Mexico			360-6240	Dioecious ⁴		Oviparous
26 Yoldia, file (<i>Yoldia limatula</i>), North Atlantic; Pacific				Dioecious ¹⁴		Oviparous

/1/ At onset. /2/ Greatest dimension. /3/ ♀ 243-351; prosomal width. /4/ Sexual dimorphism. /5/ ♀ 134-185. /6/ ♀ 44-90. /7/ ♀ 36-128. /8/ ♂ smaller. /9/ In early summer. /10/ ♀ 18-48. /11/ Average difficult to obtain because females are disposed of before reaching maximum egg-laying age under present fisheries conditions. /12/ Parthenogenetic reproduction most of season and illustrated by remaining data. /13/ Except winter. /14/ No sexual dimorphism. /15/ Protandrous hermaphrodite: male organs appear first, later replaced by female organs. /16/ Cross fertilization. /17/ Dependent on food supply.

98. REPRODUCTION: INVERTEBRATES

Fertilization of the egg can be internal (Int) or external (Ext). Sex is indicated as monocious(Mo) or dioecious (Di).

Phylum (Class) [Genus]	Fertilization	Reproduction		Adult	
		Zygote	Development	Sex	Form
1 Porifera (Calcarea) [Sycon] ¹	Int	In mesenchyme of sponge.	Amphiblastula.	Mo	Sponge.
2 Coelenterata (Hydrozoa) [Obelia] ¹	Ext	Free.	Planula-colony-medusa buds.	Di	Hydroid colony.
3 Coelenterata (Scyphozoa) [Aurelia]	Int	In folds of oral lobes.	Planula-scyphistoma-ephyrae.	Di	Medusa.
4 Coelenterata (Anthozoa) [Metridium] ¹	Ext	Free.	Planula.	Di	Polyp.
5 Platyhelminthes (Turbellaria) [Dugesia] ¹	Int	In capsule.	Development direct.	Mo ²	Planaria.
6 Platyhelminthes (Trematoda) [Fasciola]	Int	In capsule.	Miracidium-rediae-cercariae ³ .	Mo ²	Liver fluke.
7 Platyhelminthes (Cestoda) [Taenia]	Int	In capsule.	Oncosphere-hexacanth-cysticercus.	Mo ⁴	Tapeworm.
8 Rhynchocoela [Cerebratulus] ¹	Ext	Free.	Coeloblastula-pilidium	Di	Nemertine worm.
9 Rotifera [Philodina]	None	None.	Development direct.	PF ⁵	Rotifera.
10 Nematoda [Ascaris]	Int	In shell.	To juvenile stage in open; completion in host.	Di	Intestinal worm.
11 Bryozoa (Gymnolaemata) [Bugula] ¹	Int	In body of parent.	Trochophore larva.	Mo ⁴	Colony.
12 Bryozoa (Phylactolaemata) [Pectinatella] ¹	Int	In body of parent.	Ciliated hollow larva gemmates.	Mo ⁴	Colony.
13 Brachiopoda [Lingula]	Ext	Free.	Trochophore larva.	Di	Brachiopod.
14 Mollusca (Pelecypoda) [Venus]	Ext	Free.	Trochophore larva-veliger larva.	Di	Quahog.
15 Mollusca (Pelecypoda) [Anodonta]	Int	Develops in gills of parent.	Glochidium parasitic on fish gill.	Mo	Mussel.
16 Mollusca (Gastropoda) [Buccinum]	Int	In capsule.	Trochophore larva-veliger larva.	Di	Whelk.
17 Mollusca (Gastropoda) [Helix]	Int	In ground.	Development direct.	Mo ²	Snail.
18 Mollusca (Cephalopoda) [Loligo]	Int	Encased in sticky secretion.	Development direct.	Di	Squid.
19 Annelida (Polychaeta) [Nereis]	Ext	Free.	Trochophore larva.	Di	Sandworm.
20 Annelida (Oligochaeta) [Lumbricus]	Int	In capsule.	Development direct.	Mo ²	Earthworm.
21 Arthropoda (Crustacea) [Cambarus]	Int	Fastened to swimmerets.	Development direct.	Di	Crayfish.
22 Arthropoda (Insecta) [Romalea]	Int	Laid in ground.	Nymph stages.	Di	Grasshopper.
23 Arthropoda (Insecta) [Ephemera]	Int	Laid in water.	Aquatic nymph.	Di	May fly.
24 Arthropoda (Insecta) [Pieris]	Int	Laid on plants.	Caterpillar-pupa.	Di	Butterfly.
25 Arthropoda (Insecta) [Melolontha]	Int	Laid in ground.	Grub-pupa.	Di	Beetle.
26 Arthropoda (Insecta) [Apis]	Int	Laid in hive.	Larva-pupa.	Di	Honeybee.
27 Echinodermata (Asteroidea) [Asterias]	Ext	Free.	Dipleurula-bipinnaria-brachiolaria	Di	Starfish.
28 Echinodermata (Ophiuroidea) [Ophioderma]	Ext	Free.	Dipleurula-ophiopluteus.	Di	Brittle star.
29 Echinodermata (Echinoidea) [Arbacia]	Ext	Free.	Dipleurula-echinopluteus.	Di	Sea urchin.
30 Echinodermata (Holothuroidea) [Cucumaria] ¹	Ext	Free.	Dipleurula-modified auricularia.	Di	Sea cucumber.
31 Echinodermata (Crinoidea) [Antedon]	Ext	Attached to pinnules.	Dipleurula-ciliated larva-stalked crinoid.	Di	Feather star.
32 Hemichordata [Saccoglossus]	Ext	Free.	Free larva, gradual change to adult.	Di	Tongue worm.
33 Chordata (Cephalochordata) [Branchiostoma]	Ext	Free.	Development direct.	Di	Amphioxus.

/1/ Also reproduce asexually. /2/ Cross fertilization. /3/ Miracidium free, sporocysts and rediae in snails, cercariae in water or on grass where they are picked up by ruminant. /4/ Self-fertilization. /5/ Parthenogenetic female.

99. REPRODUCTION: INSECTS

Data are to be considered with caution because duration of stages varies seasonally, geographically and climatically; in some cases duration of pupal and larval stages applies only under summer conditions. Where insects breed all year regardless of season, the cycle is continuous.

E = egg; L = larva; N = nymph; P = pupa; A = adult; Cont. = continuous.

Species and Type Metamorphosis ¹		Eggs per Female	Duration, days				Over-wintering Stages	Generations per Season	Host ² ; Stage
			E	L or N	P	A			
Anoplura									
1	Louse, cattle (4 species) [I]	30-50	10-30	9-15		10-30	Cont.	7-10	Cattle; A, N
2	Louse, human (3 species) [I]	50-300	5-21	7-10		10-30	Cont.	10-12	Man; A, N
Coleoptera									
3	Beetle								
4	Black carpet (<i>Attagenus piceus</i>) [C]	42-114	6-11	238-638	6-24	32-72	L	<1	Fabric; L
5	Carpet (<i>Anthrenus scrophulariae</i>) [C]	32	10-18	66	14		Cont.	1-3	Fabric; L
6	Cigarette (<i>Lasioderma serricorne</i>) [C]	30	>6	>30	14-21	21	L	5-6	Dry food; A, L
7	Colorado potato (<i>Leptinotarsa decemlineata</i>) [C]	>500	4-9	10-21	5-10		A	1-3	Potato, etc.; A, L
8	Confused flour (<i>Tribolium confusum</i>) [C]	300-400	4-14	>22	5-18	1000	A	5-6	Grain, flour; A, L
9	Dried-fruit (<i>Carpophilus hemipterus</i>) [C]	>80	>3	28-120	>14	15		>8	Fruit; L
10	Drug-store (<i>Stegobium paniceum</i>) [C]			20-150	12-18		L	3-6	Dry food; A, L
11	Flea (<i>Systena spp</i>) [C]	500-900	5-8	14-21	10-14		A	2-3	Potato; A, L
12	May (<i>Phyllophaga fiasa</i>) [C]		21	>730	30	21-28	A, L	1	Crops, trees; A, L
13	Mexican bean (<i>Epilachna varivestis</i>) [C]	250-1200	5-14	20-35	10		A	3-4	Bean, cowpea; A, L
14	Red-legged ham (<i>Necrobis rufipes</i>) [C]	400-1000	>3	>17	>13	420	L	6-10	Meat, fish; A, L
15	Saw-toothed grain (<i>Oryzaephilus surinamensis</i>) [C]	45-285	>8	>30	>6	180-1100	Cont.	6-7	Grain, fruit; A, L
16	Striped cucumber (<i>Acalymma vittata</i>) [C]			14-40	7		A ³	1-4	Cucurbits; A, L
17	Borer, lesser grain (<i>Rhyzopertha dominica</i>) [C]	300-500						8-12	Wood, books; A, L
18	Cadelle (<i>Tenebroides mauritanicus</i>) [C]	436-1000	7-10	39-414	8-25	365	A, L	3	Grain, cereal; A, L
19	Curculio, plum (<i>Conotrachelus nenuphar</i>) [C]	41-175	4-10	17-48	8-30	3365	A	1 to >1	Peach, apple, etc.; A, L
20	Mealworm, yellow (<i>Tenebrio molitor</i>) [C]	276	12-16	>600	18-20	60-90	L	>1	Grain; L
Weevil									
21	Alfalfa (<i>Hypera postica</i>) [C]	200-800	13-17	17-21	7-14	14-21	A, E	1-2	Alfalfa; L
22	Bean (<i>Acanthoscelides obtectus</i>) [C]	200	5-20	11-40	5-18	14-63	A	2-5	Bean; L
23	Cotton boll (<i>Anthonomus grandis</i>) [C]	80-200	3-5	7-12	3-5	30-300	A	4-10	Cotton; A, L
24	Cowpea (<i>Callosobruchus maculatus</i>) [C]	82-196	4-6	9-240	5-18	15	A, L	8-10	Dried pea; L
25	Granary (<i>Sitophilus granarius</i>) [C]	50-250	4-8	19-34	5-16	210-250	Cont.	8-12	Grain; A, L
26	Sweetpotato (<i>Cylas formicarius elegantulus</i>) [C]		7	14-21	7		Cont.	6-8	Sweetpotato; A, L
Diptera									
27	Fly								
28	Horn (<i>Siphona irritans</i>) [C]	50-400	1-4	4-8	4-8	5-20	P	4-10	Cattle; A
29	Horse (<i>Tabanus atratus</i>) [C]	100-400	2-5	100-600	5-20	5-20	L	1-2	Animal; A
30	House (<i>Musca domestica</i>) [C]	75-200	1-3	4-10	4-18	10-50	Cont.	4-18	Garbage, manure; A
31	Stable (<i>Stomoxys calcitrans</i>) [C]	20-100	2-5	11-30	5-20	5-30	P	4-10	Animals; A
32	Vinegar (<i>Drosophila spp</i>) [C]		<1	3-11	2-8	14	A, L	5-6	Fruit, vegetables; A, L
33	Grub, cattle (<i>Hypoderma spp</i>) [C]	100-500	3-10	250-280	18-70	1-25	L	1	Cattle; A, L
34	Maggot, seed-corn (<i>Hyalemya ciliicrura</i>) [C]	100	1-8	10-16	10-20	30-35	Cont.	2-5	Corn, bean, etc.; L
35	Mosquito (hundreds of species) [C]	100-1036	2-1800	5-15	2-5	5-300	A, L, E	1-17	Animals; A
36	Yellow fever (<i>Aedes aegypti</i>)		2-365	6	2-3	15-60	Cont.		
37	Screwworm (<i>Callitroga americana</i>) [C]	100-300	1-2	4-5	5-40	5-30	None ⁴	2-12	Animals; L
Hemiptera									
38	Bug, harlequin (<i>Murgantia histrionica</i>) [I]	75-100	4-15	40-60		15-110	A, N	3-4	Cabbage, etc.; A, N
39	Bug, squash (<i>Anasa tristis</i>) [I]	200-300	7-14	28-42			A	1	Squash, etc.; A, N
Homoptera									
40	Aphid, melon (<i>Aphis gossypii</i>) [I] ⁵		90-120	3-7		7-28	A, E	20	Cotton, melon; A, N
41	Aphid, pea (<i>Macrosiphum pisi</i>) [I] ⁵		90-120	10			E or Cont.	7-20	Pea, clover, etc.; A, N
42	Cicada, periodical (<i>Magicicada septendecim</i>) [I]		42-49	13-17 yr		30-40	N		
43	Greenbug (<i>Toxoptera graminum</i>) [I] ⁵	3-7	90-120	6-30		26-60	A, N, E	5-20	Small grains; A, N
44	Leafhopper, beet (<i>Circulifer tenellus</i>) [I]	300-400	5-40	25-52		120-150	A	3-5	Beet, bean, etc.; A, N
45	Leafhopper, potato (<i>Empoasca fabae</i>) [I]	60-90	10	14		30	Cont.	2-4	Potato, bean; A, N
Hymenoptera									
46	Bee, honey (<i>Apis mellifera</i>) [C] ^{5,6}		3	8	9	35-40	A		
47	Sawfly, wheat stem (<i>Cephus cinctus</i>) [C]	50	7-10	300	7-10	7	L	1	Wheat, grass; L
48	Wasp, digger (<i>Tiphia vernalis</i>) [C]	50-75	8-9	120-180	180-240	30-42	P	1	Japanese beetle; L
Lepidoptera									
49	Bollworm, pink (<i>Pectinophora gossypiella</i>) [C]	200	4-10	14-21	12-18	14	L	3-6	Cotton; L
50	Borer								
51	European corn (<i>Pyrausta nubilalis</i>) [C]	400	4-9	30-40	10-14	10-24	L	1-3	Corn, etc.; L
52	Peach tree (<i>Sanninoidea exitiosa</i>) [C]	200-600	7-48	270-380	16-25	4-16	L	1	Peach, etc.; L
53	Squash vine (<i>Melittia cucurbitae</i>) [C]	150-200	7-14	30	Winter		L, P	1-2	Squash, etc.; L
54	Sugarcane (<i>Diatraea saccharalis</i>) [C]	200	4-9	20-30	6-7	7-14	L	4-5	Sugarcane; L
55	Cabbageworm, imported (<i>Pieris rapae</i>) [C]	200-500	7	14	7-14		P	3-6	Cabbage, etc.; L
56	Earworm, corn (<i>Heliothis armigera</i>) [C]	1000	2-8	13-28	14	12	P	1-7	Corn, tomato; L
57	Hornworm, tobacco (<i>Protoparce sexta</i>) [C]	200-300	7	21-28	14-28		P	1-3	Tobacco, etc.; L
58	Leafworm, cotton (<i>Alabama argillacea</i>) [C]	400-600	3-20	7-21	7-21	10-24	None in U.S. ⁴	3-8	Cotton; L
Moth									
59	Casemaking clothes (<i>Tinea pellionella</i>) [C]	>40	>6	30-100	10-90	7-28		1-2	Fabric, fur; L
60	Codling (<i>Carpocapsa pomonella</i>) [C]	6-100	4-14	15-72	7-40	3-20	L	>1 to >3	Apple, pear, etc.; L
61	Indian-meal (<i>Plodia interpunctella</i>) [C]	200-400	1-2	13-288	>8	18	L	5	Grain; L
62	Mediterranean flour (<i>Ephestia kuehniella</i>) [C]	116-700	>3	40	5-7	3-4		>6	Millproducts; L
63	Oriental fruit (<i>Grapholitha molesta</i>) [C]	100-200	3-28	10-26	5-35	2-34	L	4-7	Peach, apple; L
Mallophaga									
64	Louse, cattle biting (<i>Bovicola bovis</i>) [I]	20-50	7-30	15-25		10-30	Cont.	7-10	Cattle; A, N
Orthoptera									
65	Cockroach, American (<i>Periplaneta americana</i>) [I]	200-1000	35-100	200-400		212-303	Cont.		
66	Grasshopper (many species) [I]	300-400	90-120	40-60		>30	E	1	Crops, grass; A, N
Siphonaptera									
67	Flea (many species) [C]	50-400	2-13	7-30	7-35	8-150	Cont.	3-5	Animals; A
Thysanoptera									
68	Thrips, gladiolus (<i>Taeniothrips simplex</i>) [I]	150	4-12	4-12	3-8	26-32	A	6	Gladiolus; A, N

/1/ [I] = incomplete metamorphosis (having external development of wings); [C] = complete metamorphosis (having internal development of wings until pupal stage). /2/ Host and/or food preference. /3/ Unmated. /4/ Migrates from warmer regions in spring. /5/ Parthenogenesis. /6/ Worker bees only.

100. OVUM MORPHOLOGY: VERTEBRATES
Part I: DIMENSIONS AND GENERAL CHARACTERISTICS

Ranges, where given, are estimate "d" of the 95% range (cf Introduction).
I = isolecithal; T = telolecithal; (+) = present; (-) = absent; NR = not recognizable.

Species	Type	Polarity ¹	Diameter mm	Volume cum mm	Vitelline Membrane	Zona Pellucida ² mm	Corona Radiata	Tertiary Membranes	Transport Time ³ da	Viability hr
1 Man	I	NR	0.089-0.091 ⁴		+ ⁵	0.019-0.035 ⁶	+	-	3 ⁷	24 ⁸
2 Armadillo	I		0.080		+					
3 Bat	I	+	0.095-0.140		+	0.090-0.110	+	-	>21	
4 Cat	I	+	0.120-0.130		+	0.012-0.115	+	-	4-8	
5 Cat, marsupial	I	+	0.240	0.001	+	+	-	+ ⁹		
6 Cow	I	NR	0.135-0.157		+ ¹⁰	0.012-0.015	-	-	3-4	12-24
7 Dog	I	+	0.135-0.145		+	0.135	+	-	6-8	96-192
8 Ferret	I	+	0.116-0.132		+ ¹⁰	0.004-0.006 ¹¹	+	-	5-6	30
9 Fish	T ¹²		0.4-150	0.033-1.766						
10 Frog	T		0.7-10 ¹³	0.18-524 ¹³						
11 Goat	I	NR	0.140-0.145			0.0125	-	-	2.5-4	
12 Guinea pig	I	+	0.075-0.107		+ ¹⁰	0.012	+	-	3.5	<26
13 Horse	I	NR	0.099-0.141		+ ¹⁴	0.0135 ¹¹	-	+ ¹⁵	4	24
14 Hummingbird	T ¹²		(Shell 14 x 9.5)	113						
15 Lizard (Draco spp)	T ¹²		5	65						
16 Monkey, rhesus	I	+	0.109-0.173		+ ¹⁰	0.0115-0.034 ¹⁶	+	-	3	<24
17 Mouse	I	+	0.070-0.087	0.00036	+	+	+	-	1.45	12
18 Opossum	I	+ ¹⁷	0.130-0.160 ¹⁸	0.001	+	0.004-0.008 ¹¹	-	+ ¹⁹	2	
19 Ostrich	T ¹²		(Shell 155 x 130)							
20 Platypus	I	+	2.5-4.5 ²⁰	8.2	+	+ ¹¹	-	+ ²¹		
21 Rabbit	I	NR	0.110-0.146		+ ¹⁰	0.011-0.023	+	-	2.5-4	6
22 Rat	I	NR	0.070-0.076		+ ¹⁰	+	+	-	3	<12-33
23 Sheep	I	NR	0.120-0.180	0.0018	+ ¹⁴	0.011-0.016	-	-	2-4	12-24
24 Snake (Python)	T ¹²		120 x 60	195-226						
25 Swine	I	NR	0.120-0.140		+ ¹⁰	0.015	-	-	3-4	12-48

/1/ Of uncleaved egg. /2/ Values are mm membrane thickness. /3/ Time for ova to reach site of implantation or attachment. /4/ Unfertilized tubal egg with vitelline membrane only. With zona pellucida, 0.133; with corona radiata, 0.178-0.202. /5/ Very slight membrane, consists merely of cytoplasmic membrane of vitellus. /6/ Unfertilized tubal ova. /7/ Probably maximum time for non-segmenting ovum to reach uterine cavity. Time between fertilization and implantation, 6-7 da. /8/ Probably fertilizable for not more than 12 hr. /9/ Laminated albuminous layer and very thin shell membrane formed in the tube. /10/ Perivitelline space present. /11/ Homogenous and gelatinous. /12/ With meroblastic cleavage. /13/ Lower value for green frog, upper value for marsupial frog. /14/ Perivitelline space filled with finely granular material. /15/ In the tubal egg there is a thin albuminous coat. /16/ Clear, highly refractile membrane, sharply defined; inner third is pale iridescent blue. /17/ Determined by position of polar body. /18/ With shell membrane dimensions increase to 0.40-0.50 mm. /19/ Produced by secretory activity of oviduct, an albuminous coat 0.05 mm thick and a shell membrane 0.0012 mm thick. /20/ Shell up to 6.5. /21/ Well developed membrane, consisting of an albuminous coat (more than 2 mm thick), a shell membrane, and a parchment-like shell.

Part II: CYTOPLASM AND NUCLEUS

Species	Cytoplasm	Nucleus
1 Man	Transparent, colorless, finely granular, vitellus completely fills the space within zona.	Central. 1st polar body extruded and maturation spindle formed before ovulation. Nucleolus with chromatin.
2 Armadillo	Deutoplasmic granules.	One or two may be formed with maturation spindle. 1st spindle formed in ovary. Four young develop from one egg.
3 Bat	Fat droplets, yolk vesicles. Mitochondria concentrated in cortex.	1st polar body formed before ovulation. Polynuclear ova.
4 Cat	Deutoplasm with fat globules. Mitochondria concentrated in cortex. Polyovular follicles.	1st polar body extruded before, and 2nd maturation spindle established at ovulation. Polynuclear ova.
5 Cat, marsupial	Yolk accumulated at animal pole.	Pronuclei in granular formative cytoplasm. 1st polar body extruded in ovary.
6 Cow	Scattered fat granules (0.001-0.004 mm).	1st polar body formed before ovulation. Polynuclear ova may occur.
7 Dog	Highly refractile fat globules, so dense that vitellus is dark. Mitochondria concentrated in cortex.	Membrane, nucleolus, and/or chromatin visible; ovum discharged from ovary while nuclear material in germinative vesicle form. Polyovular follicles, polynuclear ova.
8 Ferret	Highly refractile fat granules, so dense that vitellus is dark.	1st polar body formed before ovulation. Ovulation only after coitus.
9 Goat	Fine fat granules, evenly distributed.	1st polar body formed before ovulation.
10 Guinea pig	Small fat globules at vegetal pole. Mitochondria scattered. Golgi apparatus as fenestrated membrane at periphery.	1st polar body formed before ovulation. Polynuclear ova.
11 Horse	Highly refractile fat globules, so dense that vitellus is dark.	1st polar body extruded before ovulation.
12 Monkey, rhesus	Yellowish, fine yolk granules. Vitellus fills zona. Polyovular follicles.	1st polar body extruded before ovulation. Polynuclear ova.
13 Mouse	Yellowish granular material and scattered non-fat yolk globules. Vitellus fills zona. Mitochondria first appear concentrated in periphery. Golgi bodies more numerous toward one pole.	Clear non-granular nucleus in center. 1st polar body formed in ovary. Polynuclear ova.
14 Opossum	Usually elliptical. Yolk differentiated in 3 zones. Fat chiefly in middle or submarginal zone. In some, large fat vacuole occurs at one pole, usually opposite polar body. Polyovular follicles.	1st polar body given off in ovary. Chromosomes, as with all mammals, are short rods in the form of open ring. Polynuclear ova.
15 Platypus	Bulk is formed of yellowish yolk spheres, up to 0.036 mm, dispersed in peripheral and central zone. Latebra in center of yolk.	0.014-0.20 mm in diameter. Diffusely staining, vesicular in character, has faint reticulum, dark-staining vacuolated nucleolus. 1st polar body given off in ovary. Egg normally monospermic.
16 Rabbit	Transparent. Mitochondria first appear concentrated in periphery. Golgi material is loose network of thick threads at periphery.	1st polar body extruded before ovulation. Polynuclear ova.
17 Rat	Optically heterogeneous, not transparent. 2 or 3 vacuoles detectable near center.	1st polar body formed before ovulation.
18 Sheep	Yellowish granular material, dense, numerous non-fat yolk globules. Mitochondria first appear concentrated in periphery. Polyovular follicles may occur.	1st polar body extruded before ovulation. Polynuclear ova may occur.
19 Swine	Yolk heavy with fat. Polyovular follicles may occur.	1st polar body formed before ovulation. Polynuclear ova may occur.

101. OVUM CHARACTERISTICS: MAMMALS
Part I: SEQUENCE AFTER SPERM PENETRATION

Values are hours unless otherwise specified.									
Animal	Starting Time ¹	Sperm Penetration	Second Polar Body Formation	Male Pronucleus Formation	Animal	Starting Time ¹	Sperm Penetration	Second Polar Body Formation	Male Pronucleus Formation
1 Man	O	<1 da		48 (?)	7 Hamster ²	C	6-8 ³	>6	12-24 ³
2 Cat	C	2-3 da	Not < 22		8 Mouse	C	1/4-2	5-7	6-24 ³
3 Cattle	O			11-39	9 Rabbit	C	10-13	13-14 ¹	14-18 ³
4 Ferret	C	6-30	<41	41-52	10 Rat	O	2-4	10-14+ (C)	14-35 (C)
5 Fox, silver	1st C	2-3 da	>3-4 da		11 Sheep	C			<36
6 Guinea pig	C	10	13 ¹	12-31	12 Weasel ⁴	1st C	<53-80	>74	53-80 ³

/1/ O = ovulation; C = coitus. /2/ Golden. /3/ Approximately. /4/ Long-tailed.

Part II: ZYGOTE CLEAVAGE RATES

Values are hours unless otherwise specified; those indicated with an asterisk (*) are approximate.

Animal	Starting Time	1st Cleavage Spindle	2-cell	4-cell	8-cell	16-cell	32-cell	Blastocoele Formation
1 Man	Ovulation							<5-8 da*
2 Cattle	Ovulation		27-32	27-42	31-54	50-83	4 da*	8-9 da*
3 Ferret	Coitus	53-70	51-71	64-74	64-116	95-120*	59-131*	4 ¹ / ₂ -6 da*
4 Goat	Coitus	30*	30-48*	48-60*	85*	120*		5 da*
5 Guinea pig	Coitus	27-38	23-48	30-75	80-82*	107*		115*
6 Hamster, golden	Coitus		24-36*	48-60*	72*	66-72*		78*
7 Horse			24	30-36		98-100*		
8 Mink	1st coitus		3 da*	3-4 da	4-7 da	5-6 da*	7 da*	
9 Monkey	Ovulation		26-49*	24-52*		4-6 da*		
10 Mouse	Coitus	21-28	21-43	38-50	50-64	60-70*	68-80*	66-82*
11 Pony	Ovulation		24*	33*	53*	98*		
12 Rabbit	Coitus	24	21-25	25-32	32-40	40-47*	48*	75-96*
13 Rat	Coitus	24-35	1-2 da	2-3 da	3-4 da	4 da*		4 ¹ / ₂ da*
14 Sheep	Coitus		38-39*	42*	42-44*	3 da*	4-5 da*	6-7 da*
15 Shrew	1st coitus		60-64	81				
16 Swine	Coitus	51*	25-51*	25-74*	90			5-6 da*
17 Weasel, long-tailed	1st coitus		70-85*	70-99*	99 hr- 8 da	8 da*	11 da*	11-15 da*

Part III. TRANSPORTATION OF ZYGOTE TO UTERUS AND TIME OF IMPLANTATION

Animal	Starting Time	Age or Stage at Entry	Implantation Time	Animal	Starting Time	Age or Stage at Entry	Implantation Time
1 Man	Ovulation		8-13 da	13 Hedgehog		8 cell	
2 Armadillo, 9-banded		Blastocyst	4 mo	14 Mink	1st coitus	8 da; blastocyst	25 da
3 Badger, American			2 mo	15 Monkey	Ovulation	By 16 cell	9-11 da
4 Badger, European			6 mo	16 Mouse	Coitus	66-72 hr ¹	4-5 da
5 Cat		Early blastocyst		17 Opossum	Coitus	Pronuclear stage; 24 hr	
6 Cattle	Ovulation	3-4 da; 8-16 cell	25-35 da	18 Platypus		1 cell	None
7 Deer, European roe			4 mo	19 Rabbit	Coitus	72-96 hr ¹	7-8 da
8 Echidna		1 cell	None	20 Rat	Coitus	3 ¹ / ₂ -5 da ¹	5-6 da
9 Ferret	Coitus	117-144 hr ¹		21 Sheep	Coitus	72-96 hr	9-11 da
10 Goat	Coitus	32 hr		22 Squirrel, ground	Coitus	4 da; 4 cell	4-5 da
11 Guinea pig	Coitus	3 ¹ / ₂ -4 ¹ / ₂ da; 4-8 cell	6 da	23 Swine	Coitus	4-5 da; 3-4 cell	11 da or less
12 Hamster, golden	Coitus	2 ¹ / ₂ da; 4-8 cell		24 Weasel, long-tailed	1st coitus	11-15 da ¹	8 mo

/1/ Late morula early blastocyst.

Part IV: INTRA- AND INTERSPECIFIC ZYGOTE TRANSFER

Data are for zygotes of pre-implantation stages transferred to host genital tracts.

Donor	Host	Degree of Development	Donor	Host	Degree of Development
1 Cow	Cow	To term	10 Rabbit	Rabbit	To term
2 Cow	Rabbit	One cleavage	11 Rabbit	Mouse	One cleavage
3 Goat	Goat	To term	12 Rabbit	Rat	One cleavage; blastocoele formation
4 Goat	Sheep	Dead embryo at 45 da	13 Rabbit	Guinea pig	One cleavage
5 Guinea pig	Mouse	None	14 Rat	Rat	To term
6 Mouse	Mouse	To term	15 Rat	Rabbit	None
7 Mouse	Rabbit	One cleavage	16 Rat	Mouse	None
8 Mouse	Guinea pig	Development in blastocyst shape	17 Sheep	Sheep	To term
9 Mouse	Rat	One cleavage	18 Sheep	Goat	Stillborn
			19 Swine	Swine	To term

Part V: POLYPLOID AND PARTHENOGENETIC ROUTES OF DEVELOPMENT

Type of Development	Possible Origin of Development Route ¹			Maximum State of Development Reported		
	2nd Polar Body	1st Cleavage	Sperm ³	Mouse	Rabbit	Other Mammals
1 Diploidy, normal	Normal	Normal	Present	9 ¹ / ₂ da embryo	Adult ⁴	Pig: adult ⁴
2 Triploidy	Suppressed	Normal	Present	3 ¹ / ₂ da blastula	4-cell	
3 Tetraploidy	Normal	Suppressed	Present	12-cell ⁵		
4 Hexaploidy	Suppressed	Suppressed	Present	Adults ⁶		
5 Polyploidy (evolutionary origin)				Adults ⁶	Man ⁴ ; hamster (tetraploid); rat ⁴ (± triploid)	
Parthenogenesis ⁷						
6 Haploidy	Normal	Normal	Absent	3 ¹ / ₂ da blastula	8-cell	Ferret; 4-cell; guinea pig: 1-cell; sheep: 1-cell
7 Diploidy	Suppressed	Normal	Absent	Adult		Sheep: 1-cell
8 Tetraploidy	Suppressed	Suppressed	Absent	1-cell		

/1/ Suppression of 2nd polar body (= suppression of 2nd maturation division) can double maternal chromosomes. Suppression of 1st cleavage division can double maternal and paternal chromosomes combined. Presence or absence of sperm determines presence or absence of paternal chromosomes.
/2/ Embryonic age from coition. /3/ Gynogenesis (fertilization with genetically inactivated sperm) is classified as parthenogenesis (cf Fn 7).
/4/ Controversial results. /5/ Development route probable. /6/ Indirect evidence. /7/ Parthenogenesis = development of unfertilized ovum.

102. OVUM MORPHOLOGY: INVERTEBRATES

Because of space limitations, certain symbols are used to indicate the condition typical for the organism or class to which an organism belongs. In instances where there are exceptions to type within a class the symbol is followed by an asterisk (*). Symbols apply to the columns in the table as indicated in the following key:

EGG TYPE		CLEAVAGE		BLASTULATION		GASTRULATION		MESODERM	
Homolecithal	Ho	Holoblastic	HO	Coeloblastula		Emboly	EM	Ectomesoderm	EC
Telolecithal	Te	Radial	Ra	Equal	EC	Epiboly	EP	Endomesoderm	
Centrolecithal	Ce	Biradial or disymmetrical	Bi	Unequal	UC	Polar ingression	PI	Teloblastic bands	Te
				Placula	PI	Unipolar	Un	Secondary bands	Se
				Stereoblastula	St	Many-celled	Mc	Enterocoel	En
MEMBRANE				Morula	Mo	Multipolar	Mp	Solid ingrowth	So
Viteline membrane	Vi	Spiral	Sp	Stomoblastula	So	Delamination	DE	Mesenchyme	Me
Zonal radiata	Zr	Meroblastic	ME	Superficial	Su	Simple	SI	COELOM	
Chorion	Ch	Superficial	Su	Discoblastula	Di	Coeloblastic	Co	Acoelomate	Ac
Tertiary membrane	Te	Discoidal	Di			Morula	Mo	Pseudocoelomate	Ps
		Irregular	Ir			Syncytial	Sy	Coelomate	Co
								Schizocoel	Sc
								Enterocoel	En

Phylum (Class) ¹ [Genus]	Egg Type	Membrane	Cleavage	Blastulation	Gastrulation	Mesoderm	Coelom
1 Porifera (Calcispongidae) [Scypha]	Ho		HO	EC, UC, PI, So	EM, Sy		
2 Coelenterata ² (Hydrozoa) [Tubularia]	Ho, Ce*	Te	HO, Sp*	St, Mo, Su*	All ³		
3 Coelenterata ² (Scyphozoa) [Aurelia]	Ho	Vi, Te	HO	St, Mo	EM, Mo		
4 Coelenterata ² (Anthozoa) [Urticina, Actinia]	Ho, Ce*	Ch, Te	HO	EC, Mo	EM, Mp, Co		
5 Ctenophora (Nuda) [Beroe]	Ho		Bi	UC	EP	EC	
6 Platyhelminthes (Turbellaria) [Planocera, Yungia]	Te	Vi, Te	Sp	UC, Mo	EP		Ac
7 Platyhelminthes (Trematoda) [Polystomum]	Ho	Vi	HO, Di, Ir	UC, St		EC	Ac
8 Platyhelminthes (Cestoidea) [Taenia]	Ho	Vi	Ir		EP		Ac
9 Nemertea ⁴	Te	Vi, Zr	HO, Sp	UC, St			Ac
10 Nemertea ⁴ (Heteronemertea) ⁵ [Cerebratulus]	Te	Vi, Zr	HO, Sp	UC	EM, Un	EC, Te	Ac
11 Nemertea ⁴ (Hoploneurertea) ⁵ [Tetrastemma, Prostoma]	Te	Vi, Zr	HO, Sp	UC*	Mc*		Ac
12 Acanthocephala (Archioacanthocephala) ⁵ [Macracanthorhynchus]	Te	Vi	HO, Sp	St	Un		Ps
13 Rotatoria ⁶ (Rotifera) [Asplanchna]	Te	Te	HO, Sp*		Un*	EC*	Ps
14 Gastrotricha ⁶ [Neogosseia]	Te		HO, Ir, Sp*	UC	Un		Ps
15 Nematomorpha ⁶ [Gordius, Paragordius]	Ho		HO, Bl		EM, Co*	EC, Me*	Ps
16 Nematodea ⁶ [Ascaris, Parascaris]	Ho	Vi, Te	HO, Bl	EC, PI	EP	EC, Se	Ps
17 Tardigrada [Macrobiotus]				EC	EM	En	Co, En
18 Chaetognatha [Sagitta]	Te		Ra	UC	EP	En	Co, En
19 Bryozoa (Entoprocta) [Loxosoma, Pedicellina]	Ho		HO, Sp	UC	EM	EC, Te*	Ps
20 Bryozoa (Ectoprocta) [Bugula]	Ho	Zr*	HO, Ra	UC, PI	PI, Un	Me	Co
21 Brachiopoda [Terebratulina]			HO, Sp*, Ir	EC	EM	En	Co, En
22 Phoronidea [Phoronis]				EC	EM, Un	EC, Me	Co, En
23 Enteropneusta [Saccoglossus]		Vi, Ch	HO, Bl, Ir*		EP	En	
24 Echinodermata (Crinoidea) [Antedon]	Te	Ch	Ra	UC	EM	Me, En	Co, En
25 Echinodermata (Asteroidea) [Asterias]	Ho	Ch	Ra	EC	EM	En	Co, En
26 Echinodermata (Ophiuroidea) [Amphipura]	Ho	Ch	Ra	EC	EM	En	Co, En
27 Echinodermata (Echinoidea) [Echinus]	Ho	Ch	Ra	EC	EM	En	Co, En
28 Echinodermata (Holothuroidea) [Synapta]	Ho	Ch	Ra, Su*	EC	EM	En	Co, En
29 Priapulidea ⁶ [Priapulus]	Ho		HO, Ir				Ps
30 Annelida (Archannelida) [Polygordius]	Te	Vi	HO, Sp	UC, PI	EP	EC, Te	Co, Sc
31 Annelida (Polychaeta) [Nereis, Eupomotus]	Te	Vi, Zr ⁷	HO, Sp	UC, St	EM*, EP	EC, Te	Co, Sc
32 Annelida (Oligochaeta) [Criodrilus]	Te	Vi	HO, Sp	UC, Mo	EM*, EP	EC, Te	Co, Sc
33 Annelida (Hirudinea) [Clepsine, Nephelis]	Te	Vi	HO, Sp	UC	EP	EC, Te	Co, Sc
34 Echiuroidea (Echiurida) [Echiurus, Urechis]	Te		HO, Sp	UC	EP	Te	Co, Sc
35 Sipunculoidea [Phascolosoma]		Vi, Zr	HO, Sp	UC, St*	PI, Un	EC, Te	Co, Sc
36 Onychophora [Peripatus]	Te		ME, Su	St, Su	EM, EP	Se	Co, Sc
37 Arthropoda (Pycnogonida) [Pycnogonum]			ME				Co, Sc
38 Arthropoda (Scorpiones) ⁵ [Euscorpium]	Te		ME, Di	Di	EM, Si	Se	Co, Sc
39 Arthropoda (Acari) ⁵ [Trombidium]	Ce		ME, Su	Su			Co, Sc
40 Arthropoda (Araneae) ⁵ [Aglena, Argiope]			ME, Su	Su		Se	Co, Sc
41 Arthropoda (Branchiopoda) ⁸ [Branchypus, Artemia]	Ce	Vi, Te	ME, Su	Su	Mp	Se	Co, Sc
42 Arthropoda (Cladocera) ⁸ [Daphnia]	Ce	Vi, Te	Su	Su	Mc	Se	Co, Sc
43 Arthropoda (Ostracoda) ⁸ [Cypris]	Ce	Vi, Te	ME, Su	Su	Mp	Se	Co, Sc
44 Arthropoda (Copepoda) ⁸ [Cyclops]	Ce	Vi, Te	ME, Su	Su	Un	Se	Co, Sc
45 Arthropoda (Cirripedia) ⁸ [Balanus, Lepas]	Ce	Vi, Te	ME, Su	Su	Un	Se	Co, Sc
46 Arthropoda (Mysidacea) ⁵ [Mysis]	Ce	Vi, Te	ME, Su	Su	Mp, Si	Se	Co, Sc
47 Arthropoda (Amphipoda) ⁹ [Gammarus]	Ce	Vi, Te	ME, Su	Su	Si		Co, Sc
48 Arthropoda (Decapoda) ⁵ [Gallinectes, Astacus]	Ce	Vi, Te	ME, Su	Su	Si	So	Co, Sc
49 Arthropoda ⁹ (Symphyla) [Scolopendra]	Ce	Ch	ME, Su	Su	Si	So	Co, Sc
50 Arthropoda [Musca, Dytiscus]	Ce	Vi, Zr, Ch, Te ¹⁰	ME, Su	Su			Co, Sc
51 Arthropoda (Hymenoptera) ⁵ [Platygaster]		Vi, Zr	HO, Ir				Co, Sc
52 Mollusca (Crepidopoda) [Chiton, Ischnochiton]	Te	Vi, Zr, Ch	HO, Sp	UC, St	EM, Un	EC, Te	Co, Sc
53 Mollusca (Gastropoda) [Patella, Crepidula]	Te	Te, Ch	HO, Sp	UC, St	EP, Un, Mc	EC, Te	Co, Sc
54 Mollusca (Scaphopoda) [Dentalium]	Te	Ch	HO, Sp	UC	PI, EP, Un	EC, Te	Co, Sc
55 Mollusca (Pelecypoda) [Unio, Dreissensia]	Te	Vi	HO, Sp	UC	EM, Un, Mc	EC, Te	Co, Sc
56 Mollusca (Cephalopoda) [Loligo, Sepia]	Te	Vi, Ch, Te ¹¹	ME, Di	Di	EM	Se	Co, Sc

/1/ Unless otherwise noted. /2/ Also called Cnidaria. /3/ Except EP. /4/ Also called Rhynchocoela. /5/ Order. /6/ Currently included in phylum Aschelminthes by many investigators. /7/ Identified by some observers as zona radiata, by others as cortical cytoplasm. /8/ Subclass. /9/ Also called Myriapoda. /10/ Chorion present in parasitic forms. /11/ Fertilization membrane is formed as sperm enters egg.

103. CORPUS LUTEUM OF PREGNANCY: VERTEBRATES

(A)=time of maximum development; (B)=time of appearance of retrogressive changes; (C)=period during which ovariectomy is followed by abortion. Comparable data for corpus luteum during "normal" cycles are to be found under the appropriate designations in the footnotes.

Animal	Corpus Luteum During Pregnancy	Fate of Theca Interna Cells
Mammals		
1 Man (<i>Homo sapiens</i>)	(A) 7th-10th wk. (B) Gradually from 7th to 12th wk. (C) Up to 8th wk but also performed at end of 4th wk without abortion. ¹	Form paralutein cells. "K" cells may invade gland. Form 8% of pregnancy corpus.
2 Armadillo, nine-banded (<i>Dasypus novemcinctus</i>)	Large during period of delayed implantation. (A) At implantation. (B) Middle of pregnancy. (C) At time of implantation. ²	
3 Baboon, Chacma (<i>Papio porcarius</i>)	(A) 3rd wk. (B) Falls after 4-5 wk, then constant for 26 wk. Disappears rapidly after parturition. ³	Form the vascular reticular system.
4 Bat, big-eared (<i>Corynorhinus rafinesquei</i>)	(A) Shortly after attachment of blastocyst. (B) Early in pregnancy.	
5 Bat, little brown (<i>Myotis lucifugus</i>)	Pre-ovulatory luteinization of granulosa cells. (A) 4th-5th da.	No true differentiation of theca interna occurs.
6 Bat, vampire (<i>Desmodus rotundus murinus</i>)	(A) When blastocyst is present in oviduct. (B) After mid-pregnancy.	Do not participate in gland formation.
7 Cat (<i>Felis catus</i>)	(A) 10th-16th da. (B) 20th da. Rejuvenated during lactation and may persist for 6-8 mo from mating. (C) Up to 50th da.	Migrate into gland on 2nd da. Resume fibroblastic appearance after 3rd da. Some remain at periphery.
8 Cat, marsupial (<i>Dasyurus viverrinus</i>)	(A) 3rd da. (B) Persists for 7-8 wk (lactation) then declines. No trace after 4th mo.	May contribute connective tissues.
9 Cow (<i>Bos taurus</i>)	(A) 90th da. (B) 150th da. Central cavity present in gland; marked color changes occur. (C) Always. ⁴	Invade luteal tissue from 6th da. May become connective tissue.
10 Deer, fallow (<i>Dama dama</i>)	(A) 30th da onwards. (B) Still active at 150 da.	Invade luteal tissue.
11 Dog (<i>Canis familiaris</i>)	(A) 18th da. (B) After 30th da. (C) During 1st half of pregnancy, at least. Remains throughout anestrus.	
12 Elephant, African (<i>Loxodonta africana</i>)	(A) Accessory corpora formed early or at ovulation. All regress at mid-term. (B) Replacement corpora persist until term, then decline rapidly.	Form an investing layer which retains its character after parturition.
13 Ferret (<i>Mustela furo</i>)	(A) 3rd-5th wk. (B) 3-4 da before parturition.	
14 Goat (<i>Capra hircus</i>)	(A) 30th da. (B) Slowly from 60th da. (C) Always. ⁵	Invade luteal tissue but can be distinguished for several wk.
15 Guinea pig (<i>Cavia porcellus</i>)	(A) 20 da. (B) After parturition. (C) After mid-pregnancy. ⁶	Hypertrophy and rapidly become indistinguishable from luteal cells.
16 Hamster, golden (<i>Cricetus auratus</i>)	(A) 2-3 da. (B) Rapidly after parturition. (C) Between 11th and 12th da. ⁷	
17 Hedgehog (<i>Erinaceus europaeus</i>)	(B) During lactation. ⁸	
18 Horse (<i>Equus caballus</i>)	(A) 14th da. (B) 35th-40th da followed by large crop of accessory corpora lutea which degenerate from 150th da. (C) Before 200th da. ⁹	Incorporated in luteal tissue. May hypertrophy markedly in pregnancy.
19 Mink (<i>Mustela vison</i>)	(A) 10th-12th da. Inactive phase during delayed implantation. Persists through pregnancy and 4-5 wk post-partum.	Migrate into gland 10-18 hr after ovulation.
20 Monkey (<i>Macaca mulatta</i>)	(A) Up to 19th da as on 12th da. "Transition" stage 19th-24th da. (B) 25 da. (C) Up to 25th da. ¹⁰	Retained until 4th da (not distinguishable 4th-6th da). As paralutein cells in pregnancy corpus.
21 Mouse (<i>Mus musculus</i>)	(A) 9th-11th da. (B) Present but active at parturition. (C) Throughout pregnancy. ¹¹	Proliferate actively during 1st da. Invade luteal tissue in relation to capillaries but may become connective tissue. No trace after 36-60 hr.
22 Opossum, Virginian (<i>Didelphis virginiana</i>)	(A) 3rd da. (B) 12-13 da; disappears by 3rd mo. (C) Always. ¹²	Do not contribute any glandular elements.
23 Platypus (<i>Ornithorhynchus paradoxus</i>)	(A) Time of formation of blastocyst. (B) Shortly before egg is laid.	Invade luteal tissue and also remain in groups at periphery of gland.
24 Rabbit (<i>Oryctolagus cuniculus</i>)	(A) 8th da; maximum diameter at mid-pregnancy. (B) Resorbed slowly after parturition. (C) Always followed by abortion or resorption.	Invade corpus and said to form vascular and connective tissue.
25 Rat (<i>Rattus rattus</i>)	(A) 9th-11th da. (B) Slowly after parturition. (C) Throughout pregnancy but not always after 14th da. ¹³	Early proliferation. May form luteal cells.
26 Seal, common (<i>Phoca vitulina</i>)	(B) Heavily vacuolated at parturition but persists for several weeks.	Remain as paralutein cells in early pregnancy.
27 Seal, northern fur (<i>Callorhinus ursinus</i>)	Luteal cells heavily vacuolated during delayed implantation. (A) Larger at 1 yr of age than at 2-3 mo. (B) Heavily vacuolated at parturition but persists for 2 mo more.	Remain as paralutein cells in early pregnancy but do not appear active during period of delayed implantation or from a few wk after.
28 Sheep (<i>Ovis aries</i>)	(A) Remains large from 14th da. (B) 120th-140th da. (C) May not be after 55th da. ¹⁴	Invade luteal tissue but atrophy rapidly.
29 Shrew, elephant (<i>Elephantulus myurus</i>)	(A) At 10 mm embryo stage but continues to increase in size. (B) At 30 mm embryo stage. ¹⁵	Form a core to everted corpus and may give rise to connective tissue.
30 Shrew, mole (<i>Blarina brevicauda</i>)	(A) At 3 mm embryo stage. (B) Rapid after 7 mm embryo stage; vanished at parturition.	
31 Shrew, water (<i>Neomys fodiens bicolor</i>)	Corpora merge with interstitial tissue at 4-8 cell ovum stage.	Enlarge in early pregnancy.
32 Swine (<i>Sus scrofa</i>)	(A) 75th da. (B) 110th da. ¹⁶	Some invade luteal tissue early. Some remain at periphery of gland.
33 Whale, blue (<i>Balaenoptera musculus</i>)	Appears active during pregnancy. Degenerates after parturition but corpus albicans persists for many years.	Invade gland in radial strands. May become connective tissue after parturition.
34 Whale, caaing (<i>Globiocephala melaena</i>)	(A) Young corpus has heavily vacuolated cells. (B) Persists in degenerate form after parturition.	Some remain at periphery of gland.
Birds		
35 Fowl (<i>Gallus domesticus</i>) ¹⁷	Postovulatory follicle retrogresses rapidly with no lutealization of granulosa after 2 da.	Deposit collagenous fibers and later disappear.

/1/ (A) 6th da stage of maturity. (B) 10th da onwards. /2/ Breeds in July with implantation in November. /3/ (A) 7th-8th da. (B) 13th da. /4/ (A) 9th-10th da. (B) 14th-16th da. /5/ (A) 9th da. (B) 12th da. No trace by 6 wk. /6/ (A) 9th-10th da. (B) 11th da. /7/ (A) 2nd da. (B) Rapidly after 3rd da. /8/ Granulosa cells not luteinized; gland shrinks steadily to time of next ovulation. /9/ (A) 12th-14th da. (B) 14th da. /10/ (A) 8th da. (B) 13th da. Corpora aberrantia persist 23 wk. Accessory corpora in 17% of cycles. /11/ (A) 2nd-3rd da. (B) 3rd da. /12/ (A) 3rd da. (B) 7-8 da; almost disappeared by 20th da. /13/ (A) 2nd-3rd da. (B) After 3rd da. /14/ (A) 6th-8th da. (B) 14th da; trace by 24th da. /15/ (A) At mid-dense stroma stage of uterus. (B) At same time as pre-menstrual change in uterus. /16/ (A) 6th-9th da. (B) 13th-16th da. /17/ Also, cowbird (*Molothrus bonariensis*). Removal of ruptured follicle causes holding of oviduct egg beyond time of lay 1-7 da.

103. CORPUS LUTEUM OF PREGNANCY: VERTEBRATES (Concluded)

(A)=time of maximum development; (B)=time of appearance of retrogressive changes; (C)=period during which ovariectomy is followed by abortion. Comparable data for corpus luteum during "normal" cycles are to be found under the appropriate designations in the footnotes.

Animal	Corpus Luteum During Pregnancy	Fate of Theca Interna Cells
Reptiles		
36 (Amphibolurus muricatus)	(A) 1st-2nd wk. (B) 3rd wk; disappears 2 wk after laying.	May grow into gland to provide blood vessels and connective tissue.
37 Gecko (Hoplodactylus maculatus)	(A) At 30 somite stage. (B) At 33 mm embryo stage.	Play no part in gland formation.
38 Lizard (Lygosoma quoyi)	(A) About 2nd wk. (B) End of 2nd mo.	No ingrowth among luteal cells.
39 Lizard (Xantusia vigilis)	(A) 4th wk. (B) 8th-9th wk. Disappears 4th wk post-partum.	Surround corpus. May contribute vascular and connective tissue elements.
40 Lizard, blindworm (Anguis fragilis)	Persists during development of embryo.	Remain at periphery of corpus.
41 Lizard, green (Lacerta viridis)	Present during gestation.	May give rise to connective tissue.
42 Lizard, viviparous (L. vivipara)	(A) 1 mo after ovulation. (B) End of 2nd mo. Later may give rise to supporting connective tissue of corpus.	Form peripheral cellular layer at first.
43 Snake, brown (Storeria dekayi)	Maintained throughout gestation. (B) Degenerates slowly after parturition. (C) Resorption or abortion if performed in middle of gestation.	
44 Snake, garter (Thamnophis sirtalis and T. radix)	Maintained throughout gestation. (B) Degenerates slowly after parturition. (C) Normal delivery if performed late in gestation.	Contribute to supporting tissue of corpus. Luteinization of thecal cells.
45 Snake, N. American garter (Natrix cyclopion)	Maintained throughout gestation. (B) Degenerates slowly after parturition. (C) Normal delivery if performed in late pregnancy; resorption or abortion if in early or in middle of pregnancy.	
46 Snake, sea (Enhydra schistosa)	Starts to regress slowly from 44 mm embryo stage.	Hypertrophy after ovulation and contribute connective tissue ingrowths to the gland.
47 Snake, sea (Hydrophis cyanocinctus)	(A) 195 mm embryo stage. (B) Degenerates after parturition.	Little distinction between theca interna and theca externa.
48 Turtle, box (Terrapene carolina)	Persists until egg laying. (B) Degenerated by 6-9 wk later.	Hypertrophy and form part of gland on inner aspect of theca interna and theca externa.
Fish		
49 Dogfish, spiny (Squalus acanthias)	(A) Reduced to half-size when embryo 3.5-7.5 cm. (B) Advanced at 1 yr (fetus 12-20 cm); much reduced at birth.	Form mechanical support to gland cells; not glandular.
50 Ray, fiddler (Rhinobatus granulosus)	Each ovary can contain over 20 corpora in varying stages of development.	Hypertrophy and contribute to luteal tissue.
51 Shark, basking (Cetorhinus maximus)	Corpora lutea of ovulation probably formed (4-5 mm in diameter) which gradually diminish in size. Many smaller corpora formed by atresia which persist for long time.	Form thin sheath of flattened cells.

104. CHORIO-ALLANTOIC PLACENTATION: EUTHERIAN MAMMALS

Placentation of only a small percentage of total genera in each major zoological group has been studied, hence there may be many exceptions to the data in this table. Transitional types of placentation are placed with the closest major type. Developmental stages and accessory placental areas are not considered here. Data are based solely on the most prominent overall condition of the definitive chorio-allantoic placenta. Examples of main zoological groups (with common names in brackets) for each placental type are presented in Part II.

Part I: PLACENTAL TYPE AND TISSUES

Placental Type	Maternal Tissues			Fetal Tissues	
	Endothelium	Reticulum	Epithelium	Trophoblast	Endothelium ¹
1 Epitheliochorial ²	Present	Present	Present	Present	Present
2 Endotheliochorial	Present	Present	Absent	Present	Present
3 Hemochorial ³	Absent	Absent	Absent	Present	Present
4 Hemoendothelial ⁴	Absent	Absent ⁴	Absent	Absent ⁴	Present

/1/ Maternal endothelium is probably covered by a more or less delicate net of reticulum fibers functioning as a support rather than as a transmitting layer. This presumably forms the thick hyalin-like layer seen in some carnivores (raccoon). Thin and delicate reticulum probably likewise surrounds all fetal capillaries, but is infrequently stained and therefore remains unnoticed. /2/ Syndesmochorial type is eliminated, and the forms (antelope, cattle, sheep) usually included are presented with the epitheliochorial group. The definitive functional portions of the so-called syndesmochorial placentas are actually epitheliochorial in nature. However, evidence has indicated that the epithelium lining the maternal crypts of some artiodactyls is of trophoblastic origin. If this is finally substantiated, then these forms may be in a sense syndesmochorial or endotheliochorial in type. /3/ Hemochorial placentas may be either villous or labyrinthine in type or transitional between these two (trabecular). /4/ Studies by cytological and histochemical methods and the electron microscope have indicated the persistence of an extremely thin layer of plasmoditrophoblast and reticulum.

Part II: PLACENTAL TYPE AND ZOOLOGICAL GROUPS

Epitheliochorial	Endotheliochorial	Hemochorial	Hemoendothelial
1 Insectivora (Scalopus ¹) [prairie mole]	Insectivora (Sorex ² , Blarina ² , Talpa ³) [long-, short-tailed shrew, European mole]	Insectivora (most) [shrew, mole, hedgehog]	Lagomorpha [rabbit, pika]
2 Prosimii (except Tupaiidae and Tarsiiformes) [lemur ⁴]	Chiroptera (Rhinolophus, Desmodus, Noctilio, Myotis, Rhinopoma, Pteropus, etc.) [bat]	Molossidae (in later stages) [free-tailed bat]	Rodentia (Geomys ⁵) [pocket gopher, kangaroo rat]
3 Pholidota [pangolin]	Prosimii (Tupaia) [tree shrew]	Prosimii (Tarsius) [tarsier]	
4 Cetacea [whale, dolphin, porpoise]	Edentata (Bradypus) [sloth]	Anthropoidea [man, ape, gibbon, monkey]	
5 Perissodactyla [horse]	Rodentia (Pedetes ⁵ , Castor) [S. African jumping hare, beaver]	Edentata (Myrmecophagidae, Dasypodidae) [anteater, armadillo]	
6 Artiodactyla ⁶ [ox, sheep, goat, antelope, swine, giraffe, camel, hippopotamus, cattle, deer]	Carnivora ⁷ [raccoon, dog, cat, ferret, bear, sea lion, seal]	Rodentia (most) [mouse ⁸ , rat ⁸ , squirrel, guinea pig, N. American porcupine]	
7	Tubulidentata [aardvark]	Hyracoidea [hyrax]	
8	Proboscidea [elephant]	Sirenia [manatee]	

/1/ Moles of the genera Parascalops, Scapanus and Neurotrichus appear similar but may be nearer the endotheliochorial condition. /2/ European and American shrews have been considered hemochorial. /3/ European mole passes through an endotheliochorial stage but reaches a hemochorial condition later. /4/ A small portion of the definitive placenta of Galago demidoffi (bush baby) is endotheliochorial. /5/ Only examples of this type thus far known among rodents. /6/ See Fn 2, Part I. /7/ See Fn 1, Part I. /8/ The late placentas of Myomorphs are apparently partly hemoendothelial.

105. SUMMARY: VALUES IN MAMMALIAN REPRODUCTION

Values in parentheses are estimates "d" of the 95% range (cf Introduction).

Part I: TIME INTERVALS BETWEEN VARIOUS PHASES

Species	Age of Puberty	Sexual Cycle		Duration of Estrus	Ovulation		Copulation		Sperm Transit, Vagina to Tube	Fertilization Time	Ovum Transport, Tube to Uterus da	Segmentation to Formation of Blastocoele da	Implantation or Attachment da	Gestation Period da
		Type ¹	Duration da		Time ²	Type ³	Number of Eggs Released ⁴	Time	Length					
1 Man (<i>Homo sapiens</i>)	12-15.4 yr	Pe	27-28	2-8 da	15 da ⁵ (10-13)	S	1(BA)	Any-time	15-30 min		36	5-8 ⁷	8-13	267 ⁸
2 Armadillo, 9-banded (<i>Dasypus novemcinctus</i>)	1 yr	Me					1(BA)	July-Sept			In stage of monoder-mic blastocyst		120	120 ⁹
3 Bat, greater horseshoe (<i>Rhinolophus ferrum-equinum</i>)	15 mo	Me			April	S	1(right)	Fall, spring ¹⁰						
4 Cat (<i>Felis catus</i>)	6-15 mo	Pe ¹¹	15-28	4 da ¹² , 9-10 da ¹³	24-56 hr ¹⁴	I	4-6(B)	3rd da ¹⁵	1-2 hr		2 da ¹⁴	4-8	13-14 ⁷	63(52-69)
5 Cattle (<i>Bos taurus</i>)	6-14 mo	Pe	14-23	14-18 hr	10-15.5 hr ¹⁶	S	1(BA) ¹⁷	Estrus	Seconds	6 hr	Few hr ¹⁸	3-4	8-9	281(210-335)
6 Chimpanzee (<i>Pan satyrus</i>)	9 yr	Pe	34-35	2-3 da	20 (16-24) da			Any-time ¹⁹					<10.5	(216-261)
7 Dog (<i>Canis familiaris</i>)	6-8 mo	Me	9	9 da ²⁰	1-3 da ²¹	S	8-10(B)	Estrus	1-2 hr	20 min ²²	Several da ¹⁷	6-8	13-14 ⁷	63(53-71)
8 Ferret (<i>Mustela furo</i>)		Me		Continuous ²³	30-36 hr ¹⁴	I	8-9(B)	Estrus	1-3 hr	6 hr		5-6	4.5-6 ⁷	42
9 Fox, red, silver (<i>Vulpes fulva</i>)	10 mo	Me	2-4 ²⁴	Continuous ²⁵	1-2 da ¹⁴	S	3-4 ⁷ (B)	Feb	15-20 min	8 min ¹⁴	1-2 da ¹⁸			52(49-56)
10 Goat (<i>Capra hircus</i>)	8 mo	Pe ¹¹	21	40 hr	End of estrus ⁷	S	2-4(BA)	Estrus	Seconds		2.5-4	5 ⁷		148(135-160)
11 Guinea pig (<i>Cavia porcellus</i>)	55-70 da	Pe	16-19	6-11 hr	10 hr ²¹	S	2-4(B)	Estrus		15 min	Few hr ¹⁸	3.5	6	68(58-75)
12 Hamster, golden (<i>Mesocricetus auratus</i>)	5-8 wk	Pe	4		Early estrus	S	7(B)	Estrus	Estrus ²⁶		3.27	3.25	5 or +	16(15-18)
13 Horse (<i>Equus caballus</i>)	1 yr	Pe ¹¹	10-37	4.5-9 da	24-48 hr ²⁸	S	1(BA)	Estrus	10-30 min	30 min	4		25	336(264-420)
14 Mink (<i>Mustela vison</i>)	8-9 mo	Pe ¹¹	8-9	2 da	36-50 hr ¹⁴	I	7(B)	Estrus	0.5-2.5 hr		6-7		9 ¹⁴	45-60
15 Monkey, rhesus (<i>Macaca rhesus</i>)	3 yr	Pe	28	4-6 da	(9-20) da	S	1(BA)	Any-time ²⁹			3	6-8		(146-180)
16 Mouse (<i>Mus musculus</i>)	35 da	Pe	4	9-20 hr ³⁰	2-3 hr ²¹	S	6(B)	Onset of estrus		0.25-1 hr	2 hr ¹⁴	1.45	4-5	19(19-21)
17 Opossum (<i>Didelphus virginiana</i>)	8 mo	Pe ¹¹	28	1-2 da	Early estrus			Estrus			2			12.5
18 Rabbit (<i>Oryctolagus cuniculus</i>)	5.5-8.5 mo	Pe	None ³¹	1 mo or +	10 hr ¹⁴	I	10(B)	Any-time ³²	Seconds	3-4 hr	2 hr ¹⁸	2.5-4	3-4	31(30-35)
19 Rat (<i>Rattus rattus</i>)	6-11 wk	Pe	4-6	9-20 hr ³³	8-11 hr ²¹	S	10(B)	1-4 hr ²¹		0.5-1 hr	7-10 hr ¹⁴	3	4.5	22
20 Sheep (<i>Ovis aries</i>)	7-8 mo	Pe ¹¹	16-21	24-48 hr	18-40 hr ²¹	S	1-2(BA) ¹⁷	Estrus	Seconds	5-6 hr	Few hr ¹⁸	2-4	6-7	151(144-152)
21 Swine (<i>Sus scrofa</i>)	7(5-8) mo	Pe	21	2-3	30-48 ²¹	S	6-12(B)	Estrus	1-2 hr	4-6 hr	3-4	5-6	11 or -	114(101-130)

/1/ Pe = polyestrous; Me = monestrous. /2/ Values are, unless otherwise specified, time from start of sexual (estrous) cycle. /3/ I = induced ovulation; S = spontaneous ovulation. /4/ Ovaries involved in parentheses: B = both; BA = both but alternately. /5/ Before menstruation. /6/ Probably maximum time for non-segmenting ovum to reach uterine cavity. Time between fertilization and implantation, 6-7 da. /7/ Approximately. /8/ 274-280 da from first da of last menses, 267 da from ovulation. /9/ From implantation. /10/ Sperm stored in female from October to April. /11/ Seasonally. /12/ Presence of male. /13/ Absence of male. /14/ After mating. /15/ Of estrus; most receptive at this time. /16/ From end of estrus. /17/ Right ovary predominates. /18/ From ovulation. /19/ Most receptive, 15-18 da of sexual cycle. /20/ 9 da proestrus, 9 da estrus. /21/ From onset of estrus. /22/ From beginning of copulation. /23/ March to August. /24/ Period of receptivity. /25/ December to March. /26/ 8-10 P.M. /27/ Morula or blastocyst. /28/ Before end of estrus. /29/ Most receptive 2 da before ovulation. /30/ Begins 10 P.M.-1 A.M. /31/ Cycle indefinite; growth of follicles in waves of 16 da. /32/ Most receptive in estrus. /33/ Begins 4-10 PM.

Part II: MISCELLANEOUS OTHER DATA

Species	Chromosome Number 2n	Age at First Breeding mo	Return to Estrous Cycle, Post-partum	Reproduction Interval	Optimum Breeding Period	Sperm Deposit Site	Sperm		Fertilization Site ³	Placenta			Follicle Size, Ovulation	Ovum Viability, Unfertilized hr
							Time of Transit ¹ min	Fertility in vivo ² hr		Morphologic Type	Histologic Type	Uterine Mucosa		
1 Man	46													
2 Cat	38	10 ⁴	2-3 wk ⁵	Varies ⁶	Varies ⁷		100		Oviduct ⁸	Discoid	Hemochorial	Deciduate		
3 Cattle	60	15-24 ⁴	7-105 da	13-15 mo ⁴	Mid-late estrus	Anterior vagina	2.5-140	to 28	Fallopian tube	Zonary to discoid	Endochorial	Deciduate	10-20 mm ⁹	12
4 Dog	78	6-8 ¹⁰	30-90 da ⁴	5-12 mo	Estrus every 2nd da ¹¹	Anterior vagina or cervix	20		Fallopian tube ¹²	Cotyledonary	Mesochorial	Semiplacenta	10 mm ⁹	96-192
5 Goat	60	5-18 ⁴	Next season	Annual	Mid-late estrus	Anterior vagina			Fallopian tube	Cotyledonary	Mesochorial	Semiplacenta		
6 Guinea pig	33	1.5-2	6-8 hr	Varies ¹³	May-estrus ¹⁵	Uterus		22	Fallopian tube	Discoid	Hemochorial	Semiplacenta	0.8 mm	to 30
7 Horse	60	24-36	9-11 da	12-24 mo	Late estrus	Uterus	15		Fallopian tube	Diffuse	Epichorial	Nondeciduate	3.5-5.5 cm	
8 Mouse	40	2.5-3.5	2-4 da ¹⁴	Varies ¹³	Varies ¹⁵	Uterus	to 15		Fallopian tube ¹⁶	Discoid	Hemochorial	True	0.5 mm	
9 Rabbit	22	3.5-4.5 ¹⁷	Immediate	Varies ⁶	May-July ¹⁸	Anterior vagina or cervix	5-240	to 30	Fallopian tube ¹⁹	Discoid	Hemochorial	True	1.8 mm ⁹	6
10 Rat	42	1.5-2.5	2-4 da ¹⁴	Varies ¹³	Varies ¹⁵	Uterus	to 15	14	Fallopian tube ¹⁶	Discoid	Hemochorial	True	0.9 mm	16-17 ²⁰
11 Sheep	54	6-18 ⁴	Next season	Annual	Mid-late estrus	Anterior vagina	10-30		Fallopian tube	Cotyledonary	Mesochorial	Semiplacenta	15-19 mm	12-24
12 Swine	40	5-10 ⁴	3-4 da ^{4,5}	5-12 mo ⁴	Late mid-estrus	Cervix			Fallopian tube	Diffuse	Epichorial	Nondeciduate	7-10 mm	to 12

/1/ From cervix to ovarian end of oviduct (Fallopian tube). /2/ In female genital tract. /3/ Implantation site: uterine horn. /4/ Variable. /5/ After weaning. /6/ May reproduce continually. /7/ Geographically influenced. /8/ Upper third. /9/ Diameter. /10/ Or first estrus. /11/ Also anytime after 4th da of estrus. /12/ Probably middle half. /13/ With strain or management. /14/ After removal of litter. /15/ With strain. /16/ Ovarian end. /17/ Fall born; spring born, 6.5-7.5 mo. /18/ In USA. /19/ Upper half. /20/ In oviduct.

Part III: SURVIVAL IN VITRO: SPERM

Species	Method of Collecting Semen ¹	Diluent		Sperm-Extender Ratio	Cooling °C/min	Storage Temperature °C	Storage Time ²	Insemination		
		Ratio	Substance					Site	Time	Volume cc
1 Cattle	A	1:1	2.9% Na citrate dihydrate: egg yolk ³ + 0.3% sulfanilamide + 500 µg/ml dihydrostreptomycin.	<1:200 (>11,000,000 sperm/ml)	1	5	<48	Cervix or uterus	End of estrus	1-2
2 Dog	A or M	5:1	None	1:1	1	5	0	Cervix ⁴	11-13 da ⁵	1-10
3 Horse	A		5% glucose in H ₂ O: egg yolk.	1:1	1	5	<40	Uterus	12-20 hr ⁶	10-50
4 Mouse	S		Locke's solution	1:4			0	Uterus ⁷	1.5-2.5 hr ⁸	0.02-0.10
5 Rabbit	A		Krebs' solution ⁹				0	Anterior of vagina	After mating ¹⁰	0.25-1.0
6 Rat	S		Locke's solution ¹¹				0	Cervix ¹²	Estrus	0.1-0.2 ¹³
7 Sheep, goat	A		As cattle ¹⁴	<1:11 (>11,000,000 sperm/ml)	1	5	<48	Cervix	Last half of estrus	0.1-0.2
8 Swine	A		Krebs' solution	1:2.5 ¹⁵ ; 1:5 ¹⁶			0	Cervix or uterus ⁴	12-23 hr ⁶	50 ¹⁵ ; 250 ¹⁶

/1/ A-artificial vagina; M-manual manipulation; S-stripping sperm from vas deferens. /2/ Use immediately without storage. /3/ Fresh. /4/ Place cotton plug in vagina after insemination. /5/ After first bleeding. /6/ After onset of estrus. /7/ By laparotomy, female under ether anesthesia. /8/ After mating with vasectomized male. /9/ Modified. /10/ With vasectomized buck. /11/ Dilution must produce thick, viscid suspension. /12/ Female anesthetized; plug vagina with cotton dipped into secretions from seminal vesicles and coagulating fluid. /13/ Into each cervical canal. /14/ Necessity of bacterial antigens unknown. /15/ Gilts. /16/ Sows.

106. PREGNANCY TESTS: MAN

Test ¹		Test Animals	Duration of Test	Source of Test Material	Substance Tested For:	Earliest Positive Indications	Positive Diagnostic Findings	Accuracy ²		Remarks
								True +	False -	
1	Aschheim-Zondek	3-4 female mice, 3-4 wk old; 6-8 g	96-100 hr	1st morning urine.	Chorionic gonadotropin.	10 da-2 wk after 1st missed menses.	Hemorrhagic follicles on ovary; corpora lutea containing entrapped ovum.	6	3.5	Sensitive; accurate; reliable; expensive(?); time consuming; occasional false positives caused by maturation of mouse ovaries ³ .
2	Ovarian hyperemia ⁴	2-3 immature female rats; 45-60 g	1-24 hr	1st morning urine.	Chorionic gonadotropin.	1-2 wk after 1st missed menses.	Ovary usually enlarged; diffuse reddening or many distinct red spots.	1-2	10	Difficult end point; false negatives are common; very rapid test ⁴ .
3	Friedman	Mature female rabbits, 3-4 lb; previously isolated 4 wk	18-24 hr	1st morning urine.	Chorionic gonadotropin.	1-2 wk after 1st missed menses.	Early corpora lutea; ova can be washed from tubes; hemorrhagic follicles.	1	2-3	Animals need not be sacrificed; rapid but expensive test.
4	Galli-Mainini	Male frog (<i>Rana pipiens</i>) or male toad (<i>Bufo arenarum</i>)	10-120 min	1st morning urine, or blood serum.	Chorionic gonadotropin.	2 wk after 1st missed menses.	Spermatozoa in urine collected from cloacal region; examined microscopically pre- and post-injection.	0(?) ⁵	2 ⁵	Less sensitive in summer months, in early pregnancy, presence of jaundice; inexpensive; animals need not be sacrificed.
5	Hogben	Segregated female S. African clawed "toad" (<i>Xenopus laevis</i>)	5-18 hr	1st morning urine.	Chorionic gonadotropin.	1-2 wk after 1st missed menses.	Presence of egg mass on floor of container housing toad.	0 ⁶	0.2 ⁶	Simple end point; animals need not be sacrificed and may be used repeatedly; rapid, accurate test.
6	Delfs	Immature female rats, 21-23 da old; 34-42 g	72-96 hr	Blood serum; pooled urine.	Total chorionic gonadotropin.	After 1st missed menses.	Uterine weight increase (vs controls) determined at 72 hr post-injection.	17	24	Used primarily as quantitative assay (in trained hands) of chorionic gonadotropin levels.
7	Guterman		3 hr	1st morning urine.	Pregnanediol.	At time of 1st missed menses.	Development of color complex; orange to deep orange-brown with sulfuric acid.	7-8	8-9	Valuable(?) in abortion and hydatidiform mole; false positives: (a) late in menstrual cycle; (b) progesterone treatment; (c) luteal cysts; (d) pseudocyesis.
8	Kapeller-Adler		$\frac{1}{2}$ hr	1st morning urine.	Histidine.	1st wk after missed menses.	Colorimetric qualitative and quantitative.	10	11	Simple; inexpensive; urine constituents alter color reaction as do catabolic products in urine. Non-specific(?).
9	Visscher-Bowman		$\frac{1}{2}$ hr	1st morning urine.	Chorionic gonadotropin(?).	After 1st missed menses.	Russet color reaction with flocculation.	8	11	Simple; inexpensive; false positives: (a) in fever; (b) excess of catabolic products in urine. Non-specific(?).
10	Gilfillen-Gregg		$\frac{1}{2}$ -1 hr	Injection of chorionic gonadotropin.		After 1st missed menses.	No skin reaction in pregnancy, i.e., hypoallergy to chorionic gonadotropin.	22	13	Simple, but interpretation difficult; limited in Negroes.
11	Basal temperature deviations			Temperature, rectal or oral.		Ante- and post-conception observation.	Luteal phase temperature sustained for more than 16 da (preceded by a characteristic biphasic curve) ⁷ .	3	0(?)	Early diagnosis of pregnancy; false positives: (a) mild febrile illness; (b) changes in climate; (c) pseudocyesis; (d) persistent corpus luteum.
12	Schwartz		3-7 da	Estrone and progesterone injections daily, or oral estrogen and progesterone.		At time of 1st missed menses.	Continued amenorrhea with otherwise normal menstrual cycles and no demonstrable pelvic disease.	High degree of accuracy		Simple; inexpensive(?); false positives: (a) ectopic pregnancy when patient is spotting; (b) amenorrhea of more than 6 mo duration; (c) pseudocyesis; (d) persistent corpus luteum.
13	Richardson		$\frac{1}{2}$ hr	1st morning urine; blood serum or saliva.	Estrogens.	At time of 1st missed menses.	Development of color complex with phenylhydrazine, phenylsulfone.	2	2	False positives in hyperestronism; ovarian tumor; of value in diagnosis of hydatidiform mole. Non-specificity(?) can cause false reactions.
14	Colostrum "Q"		1 hr	Colostrum.	Immune reaction to protein of colostrum.	2 wk after 1st missed menses.	Pregnancy: disappearance of original wheal in 30 min. Non-pregnant: enlargement of wheal 2-3 times with red areola.	5	2	Unreliable in hyperallergic individuals and Negroes; false positives in menopause and during menstrual period.

/1/ Tests 1-6, 9(?) depend on physiological reactions of test animal to chorionic gonadotropin present in pregnancy urine. /2/ Claimed. /3/ False positives may also occur during depression of ovarian function (e.g., menopause). /4/ A recent modification of this test involves the addition of a pituitary synergist; the duration of the test is reduced to 1-3 hr, false positives to 0.1%, false negatives to 2%, and the end point is much more definite. /5/ False positives have been reported, and a percentage of false negatives as high as 16. /6/ False positives of 1%, and false negatives up to 4% have been reported. /7/ The luteal phase is partially biphasic.

107. LIFE CYCLE AND SEXUAL MECHANISM: ALGAE AND FUNGI

Terms followed by an asterisk (*) are defined in the Glossary Part VI.

Part I: LIFE CYCLE, SEXUALITY, AND SEXUAL MECHANISM: ALGAE

Data in columns B and D refer to the corresponding patterns presented in Parts III and V. In column C, M = monoecious*; D = dioecious*.

Species	Life Cycle Type	Pattern of Sexuality	Sexual Mechanism and Development	Species	Life Cycle Type	Pattern of Sexuality	Sexual Mechanism and Development
(A)	(B)	(C)	(D)	(A)	(B)	(C)	(D)
Chlorophyta				Chrysophyta			
1 Chlamydomonas paupera	B	M	3-5-10	32 Xanthophyceae, most spp	A		
2 C. eugametos	B	D	3-5-10	33 Botrydium granulosum	B	M & D ⁴	3-7-9-10
3 Volvox aureus	B	D ¹	3-7-9-10	34 Vaucheria sessilis	B	M	3-8-9-10
4 V. globator	B	M	3-7-9-10	35 V. dichotoma	B	D	3-8-9-10
5 Tetraspora lubrica	B	D	3-7-9-10	36 Chrysophyceae, most spp	A		
6 Sphaerocystis schroeterii	A			37 Ochrosphaera neopolitana	B	M	3-7-9-10
7 Chlorella vulgaris	A			38 Centrales, most spp	A		
8 Chlorococcum humicolor	B	M	3-7-9-10	39 Cyclotella meneghiniana	G	M	1-10
9 Dictyosphaerium indicum	B	D	3-7-9-10	40 Amphora normani	G	M	1-10
10 Hydrodictyon reticulatum	B	M	3-7-9-10	41 Rhopalodia gibba	G	D	1-10
11 Protosiphon botryoides	B	M	3-7-9-10	Pyrrophyta			
12 Chlorochytridium lemnae	G	?	1-10	42 Peridinium wisconsinensis	A		
13 Ulothrix rorida	B	M	3-7-9-10	Phaeophyta			
14 U. zonata	B	D	3-7-9-10	43 Pylaiella rufincola	A		
15 Ulva lactuca	F	D	3-7-9-10	44 Ectocarpus siliculosus	F	D	3-8-9-10
16 Cladophora suhrina	F	D	3-7-9-10	45 Sphacelaria bipinnata	F	M	3-8-9-10
17 C. glomerata	G	M	1-10	46 Lamanaria saccharina	F	D	3-8-9-10
18 Protococcus viridis	A			47 Pelvetia fastigiata	G ⁵	M	1-10
19 Draparnaldiopsis indica	F	D	3-7-9-10	48 Fucus vesiculosus	G ⁵	D	1-10
20 Coleochaete pulvinata	B	M	3-8-9-10	Rhodophyta			
21 C. scutata	B	D	3-8-9-10	49 Rhodospira	A		
22 Oedogonium kurzii	B	M	3-7-9-10	50 Porphyra elongata	B	M	3-7-9-11
23 O. grande	B	D	3-7-9-10	51 P. dentata	B	D	3-7-9-11
24 O. crassiusculum	B	M	See Fn 2	52 Batrachospermum moniliforme	B	M	3-8-9-11
25 O. spirale	B	D	See Fn 2	53 B. elegans	B	D	3-8-9-11
26 Spirogyra setiformis	B	D	(3)-7-12 ³	54 Polysiphonia violacea	F	D	3-8-9-11
27 S. granulata	B	M	(3)-7-12	55 Griffithsia barbata	F	M	3-8-9-11
28 Dasycladus claviformis	G	D ⁴	1-10	Cyanophyta			
29 Bryopsis pulvinata	G	M	1-10	56 All species	A		
30 Chara fragilis	B	M	3-8-9-10				
31 Nitella capitata	B	D	3-8-9-10				

/1/ Dioecism is not absolute; colonies with both eggs and sperm have been reported. /2/ Species produces, in lieu of antheridia, specialized swarmers (androspores) which come to rest upon or near the oogonium and develop into dwarf male plants, each of which bears 1 to 4 antheridia. /3/ The fusing elements of the species are commonly termed gametes but are here considered gametangia because of the low degree of morphological differentiation. The copulatory process in these forms approaches somatic copulation, the sexual fusion of vegetative cells common in higher fungi. /4/ Species includes monoecious and dioecious varieties. /5/ Species commonly with 2 haploid nuclear generations in the oogonium and 4 in the antheridium.

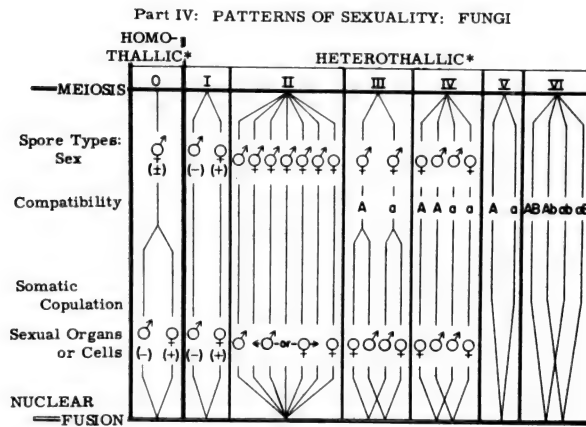
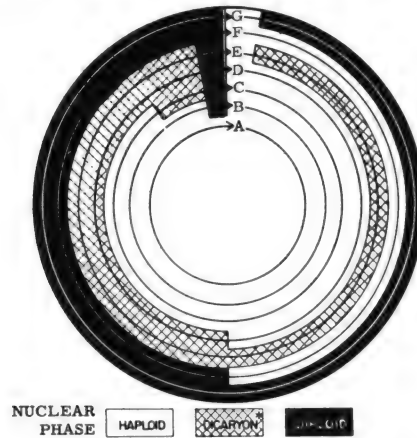
Part II: LIFE CYCLE, SEXUALITY, AND SEXUAL MECHANISM: FUNGI

Data in columns B, C, D refer to the corresponding patterns presented in Parts III, IV, V.

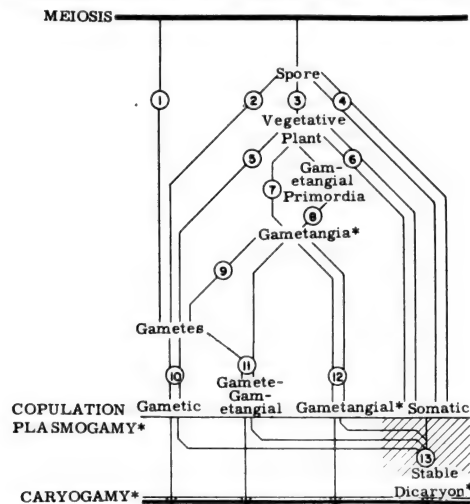
Species	Life Cycle Type	Pattern of Sexuality	Sexual Mechanism and Development	Species	Life Cycle Type	Pattern of Sexuality	Sexual Mechanism and Development
(A)	(B)	(C)	(D)	(A)	(B)	(C)	(D)
Myxomycetes				Ascomycetes (concluded)			
1 Labyrinthula macrocystis	A			34 Penicillium luteum	C	O	3-8-12-13
2 Dictyostelium discoideum	B	O	3-5-10	35 Sphaerotheca fuliginea	C ⁶	O	3-8-12-13
3 Physarum polycephalum	G ¹	?	2-10	36 Erysiphe cichoracearum	C	I/III ³	3-8-12-13
4 Plasmodiophora brassica	F	?	3-7-9-10	37 Neurospora sitophila	C	III	3-8-9-11-13
Phycomycetes				38 Pleurage anserina	C	III ⁷	3-8-9-11-13
5 Olpidium viciae	B	?	3-7-9-10	39 Sordaria fimicola	C	O	3-8-12-13
6 Polyphagus euglenae	B	I	3-7-12	40 Venturia inaequalis	C	I/III	3-8-12-13
7 Allomyces javanicus	F	O	3-8-9-10	41 Glomerella cingulata	C	O ⁸	3-8-12-13
8 A. cystogenus	G ²	?	1-10	42 Mycosphaerella tulipifera	C	?	3-8-9-11-13
9 A. anomalous	A			43 Hypomyces solani f. cucurbitae	C	IV	3-8-9-11-13
10 Blastocladiella variabilis	F	I	3-7-9-10	44 Claviceps purpurea	C	?	3-8-12-13
11 Monoblepharis sphaerica	B	O	3-8-9-10	45 Stigmatomyces baeri	C	O	3-8-9-11-13
12 Myzochytrium vermicola	B	O	3-7-12	46 Amorphomyces falagriae	C	I	3-8-9-11-13
13 Lagenidium rabenhorstii	B	I ³	3-7-12	47 Pyronema confluens	C	O	3-8-12-13
14 Achlya ambisexualis	B	II	3-8-9-11	48 Sclerotinia gladioli	C	III	3-8-9-11-13
15 A. americana	B	O	3-8-9-11	49 Ascobolus magnificus	C	III	3-8-12-13
16 Saproscyces renschii	B	II	3-8-9-11	Basidiomycetes			
17 S. androgynous	B	O	3-8-9-11	50 Stereum hirsutum	D	O	3-6-13
18 Phytophthora omnivora	B	II	3-8-9-11	51 Fomes pinicola	D	V ⁹	3-6-13
19 P. erythrosetica	B	O	3-8-9-11	52 Aleurodiscus polygonius	D	VI ⁹	3-6-13
20 Phycomyces blakesleeanae	B	I	3-8-12	53 A. canadensis	E	O ^{7, 10}	(4)-13
21 Sporodinia grandis	B	O	3-8-12	54 Coprinus stercorearius	D	O	3-6-13
22 Basidiobolus ranarum	B	O	3-7-12	55 C. comatus	D	V ⁹	3-6-13
23 Entomophthora sepulchralis	B	O	3-8-12	56 Schizophyllum commune	D	VI ⁹	3-6-13
Ascomycetes				57 Galera pubescens f. bispora	E	O ^{7, 11}	(4)-13
24 Eremascus fertilis	B	O	3-8-12	58 Cyathus striatus	D	VI ⁹	3-6-13
25 Schizosaccharomyces octosporus	B	O	3-5-10	59 Exidia glandulosa	D	V ⁹	3-6-13
26 Zygosaccharomyces lactis	B	V	3-5-10	60 Calocera cornea	E	O ^{7, 11}	(4)-13
27 Saccharomyces ludwigii	G	V	2-10	61 Auricularia auricula-judae	D	V ⁹	3-6-13
28 Saccharomyces ellipsoideus	G ⁴	V ⁵	2-10	62 Phleogenia fagina	D	O	3-6-13
29 S. fragilis	G	O	2-10	63 Puccinia graminis	D	III	3-8-9-11-13
30 Candida albicans	A						or 3-6-13
31 Taphrina epiphylla	D-E	V	3-5-10-13	64 P. xanthi	D	O	3-6-13
32 Aspergillus niger	A			65 Graphiola phonicis	C	O	3-6-13
33 A. repens	C	O	3-8-12-13	66 Ustilago violacea	E	V	4-13 or 3-6-13

/1/ Haploid phase may consist of one to few nuclear generation. /2/ One mitotic division of haploid nucleus interposed between meiosis and gametic fusion. /3/ Type of heterothallism unknown. /4/ Haploid phase may vary in duration from a single nuclear generation, i.e., in the fusion of ascospores, to many generations involving an extended haploid vegetative stage. /5/ Genetic (compatibility) factors governing mating type may be relatively unstable, a condition termed "partial heterothallism." /6/ Dicaryon may be limited to a single cell, the ascus initial. /7/ Two nuclei of opposed compatibilities regularly included in the ascospore, which germinates to produce a self-fertile, heterokaryotic mycelium, a condition termed "secondary homothallism." /8/ Basically homothallic but may be "partial heterothallic." /9/ Mating behavior is determined by multiple allelomorphs (incompatibility factors at one locus, V (bipolar sexuality), or at two loci, VI (tetrapolar sexuality). /10/ Genetically bipolar and secondarily homothallic. /11/ Secondarily homothallic.

107. LIFE CYCLE AND SEXUAL MECHANISM: ALGAE AND FUNGI (Concluded)
 Part III: TYPES OF LIFE CYCLES: NUCLEAR PHASE
 Schematic representation of the occurrence and relative duration of the 3 nuclear phases in algae and fungi.



Part V: SEXUAL MECHANISMS AND DEVELOPMENT PATTERNS: ALGAE AND FUNGI



Part VI: GLOSSARY

Caryogamy: Sexual fusion of 2 nuclei. Dicaryon: Condition of cells, containing 2 nuclei brought together usually by a sexual process and which divide in unison. Dioecious: Individual plants are unisexual. Gametangium: A cell or organ in which gametes are formed. Sometimes gamete formation is suppressed and a gametangium itself may function in copulation. Heterothallism: Condition in which 2 self-sterile strains are necessary to form the sexual stage. Homothallism: Condition in which the organism is sexually self-fertile. Monoecious: Individual plants produce both kinds of gametes or sex organs. Plasmogamy: Sexual fusion of 2 cells without fusion of nuclei.

108. HETEROTHALLISM AND HOMOTHALLISM: FUNGI

MH=morphological heterothallism; PH=physiological heterothallism; multiple factors: b=bipolar, t=tetrapolar, m=evidence for multiple factors; H=homothallism; H2=secondary homothallism. Relative degree of maleness and femaleness, as well as detectable but not absolute heterothallism, is indicated by (rel). Available evidence implies that organisms 1-83, indicated as PH, have only 2 mating types in a population; the Basidiomycetes, excluding most rusts and smuts, have multiple mating types. Morphological heterothallism and secondary homothallism are categories as defined by Whitehouse, H. L. K., in Biol. Rev., 24: 411, 1949.

Species			Type	Species	Type	Species	Type
1	Phycomycetes: general				144	Hebeloma circinans,	
2	Achlya ambisexualis	H(rel)	71	Basidiomycetes: Tremellales	PHbm	H. truncatum	PHt
3	A. regularis	MH	72	Auricularia auricula-judae	Phb	Hydnum auriscalpium	PHt
4	Blastocladiella cystogena,		73	Dactyomyces deliquescens	PHbm	Hypholoma spp	PHt
	B. stubenii	PH	74	Exidia glandulosa	PH	Inocybe tricholoma	PHt
5	Dictyuchus spp	MH	75	E. nucleata	PHbm	Irpex fuscoviolaceus,	
6	Peronospora parasitica	H(rel)	76	E. recesa, E. saccharina	Phb	I. pendulus	PHt
7	Phytophthora parasitica	MH(rel)	77	Femsjonia luteo-alba	PHb	Lentinus urinus	PHt
8	Sapromyces renschii	MH(rel)		Pilacre faginea	PHb	Lenzites betulina	PHtm
	Zoophagus insidians	MH	78	Basidiomycetes: Ustilaginales		L. malaecensis	PH
9	Phycomycetes: Mucorales		79	Sphacelotheca spp	PH	L. saepiaria	PHb
10	Absidia spp	PH	80	Tilletia caries, T. foetida	PH	L. tiguris	PHt
11	Blakeslea trispora	PH	81	Ustilago spp	PH	Leptoporus adustus	PHb
12	Chaetocladium brefeldii	PH	82	Basidiomycetes: Uredinales		L. imberbis, L. ostreiformis	PHb
13	Choanephora conjuncta	PH	83	Cronartium ribicola	PH	Leucoporus arcularius,	
14	C. cucurbitarum	PH	84	Gymnosporangium globosum	PH	L. brumalis	PHt
15	Circinella spinosa, C. umbellata	PH	85	G. haraeum	PH	Marasmius cohaereus	PHb
16	Cunninghamella bertholletiae	PH	86	G. juniperi-virginianae	PHb	M. elongatipes	PHt
17	C. echinata, C. elegans	PH	87	Melampsora lini	PHb	M. oreades	PH
18	Helicostylum piriforme	PH	88	Phragmidium speciosum	PHb	M. personatus	PHt
19	Mucor spp	PH	89	Puccinia spp	PHb	Marasmius spp	PHt
20	Parasitella simplex	PH	90	Uromyces appendiculatus	PHb	Merulius rufus	PHb
	Phycomyces blakesleeanus,		91	U. vignae	PHb	Mycena spp	H
	P. nitens	PH	92	Basidiomycetes: Agaricales		Mycena spp	PHt
21	Rhizopus nigricans	PH	93	Agaricus campestris	H	Odontia bicolor, O. separans	PH
22	Syncephalastrum racemosum	PH	94	Agrocybe dura	PHt	O. setigera	PHb
	Ascomycetes: general		95	A. pediales,		O. sudans	PHt
23	Ascobolus spp	PH	96	A. semiobicularis	PHb	Omphalia mairei	PH
24	Ascophanus granulatus	PH	97	A. sphaleromorpha	PH	O. maura	PHt
25	Aspergillus fischeri	H	98	Armillaria mucida	PHt	O. maura alba	PHb
26	A. glaucus, A. repens	H	99	Clitocybe aurantiaca	PHt	Panaeolina foenicisecii	PH
27	Bombardia lunata	PH	100	C. cyathiformis	PHb	Panaeolus acuminatus	PHb
28	Ceratostomella spp	PH	101	C. bicolor, C. gallinacea,		P. campanulatus	PHt
29	Cercospora caudae-suis	H	102	C. gigantea	PHt	P. fimicola	PH
30	Chaetomium spp	H	103	C. radicellata	PH	Panellus mitis	PHt
31	Diaporthe phaseolorum	PH	104	Collybia spp	PHt	Panus stipticus	PHtm
32	Endoconidiophora fagearum	PH	105	Conocybe pubescens	PHt, H2	Peniophora spp	PHb
33	Erysiphe cichoraceorum	PH	106	C. spicula	PHt	P. candida	PHt
34	Fimetaria fimicola	H	107	Coprinus spp	PHb	P. ciliata	PH
35	Gelasinospira tetrasperma	H	108	Coprinus spp	PHt	P. cinerea, P. farinosa	PHt
36	Gibberella moniliformis	PH	109	C. amphithallus	PHt ¹	Phlebia aurantiaca	PHb
37	Monascus spp	H	110	C. angulatus, C. callinus	PHtm	Pholiota adiposa, P. aurivella	PHb
38	Neurospora crassa	PH	111	C. bisporus	H	P. cylindracea, P. mutabilis	PHt
39	N. tetrasperma	H2	112	C. comatus	PHbm	Pleurotus spp	PHt
40	Patella melaloma	PH	113	C. hiassens, C. meueus	PHtm	Polyporus anceps	PHbm
41	Penicillium spp	H	114	C. pellucidus	H	P. borealis	PHt
42	Pleuraea spp	H	115	C. sasii	PHb ¹	P. tuckahoe	PH
43	P. anserina	H2	116	C. sclerocystidiosus	PHtm	Poria microspora	PHbm
44	Podospora minuta	PH, H2	117	C. silvaticus	PH	P. mucida	PHt
45	Sclerotinia sclerotiorum	H	118	C. stellatus	H	Psathyrella spp	PHt
46	Stromatinia gladioli	PH	119	Coriolus abietinus	PHtm	Pseudocoprinus disseminatus	PHbm
47	S. narcissi	MH	120	C. hirsutus	PHb	P. impatiens	PHtm
48	Taphrina deformans	H	121	C. versicolor	PHt	Psilocybe foenicisecii	PHt
49	T. epiphylla, T. klebahnii	PH	122	Corninellus shutake	PHb	P. subviscida	PH
50	Venturia inaequalis, V. pirina	PH	123	Corticium bombycinum	PHt	Radulum orbiculare	PHbm
	Ascomycetes: Laboulbeniaceae		124	C. calceum	PH	Rhodopaxillus nudus	PH
51	Amorphomyces spp	MH	125	C. conigenum	PHb	Schizophyllum commune	PHtm
52	Apatomyces laboulbenioides	MH	126	C. coronilla	PHbt, H	Solenia anomala	PHb
53	Aporomyces subulatus	MH	127	C. effuscatum	PHtm	Sprassia crispa	PHb
54	A. trinitatis, A. uniflagellatus	MH	128	C. evolvens	PHt	Stereum chilletii	PHt
55	Chitonomyces, all species	MH	129	C. hydnans	PH	S. murrayi	PH
56	Dicranomyces terminalis	MH	130	C. incurstans	PHb	S. rufum	PHt
57	Dimeromyces, all species	MH	131	C. laeve	PH	S. spadiceum	PHb
58	Dimorphomyces denticatus,		132	C. polygonium	PHt	S. sanguinolentum	H
	D. muticus	MH	133	C. porosum, C. radiosum	PH	Stropharia semiglobata	PHbm
59	Dioicomyces spp	MH	134	C. serum	PHt	Trametes cinnabarina	PHt
60	Eudimeromyces, all species	MH	135	Cortinellus berkeleyana	PHt	T. suaveolens	PHtm
61	Herpomyces spp	MH	136	Crinipellis stipitarius	PHt	Typhula erythropus	PHt
62	Nanomyces appendiculatus	MH	137	Cytidia flocculenta, C. salicina	PHt	T. gyrans, T. trifolii	PH
63	N. fijianus,		138	Deconica atrorufal,		Xeromphalina campanella	PHt
	N. perpendicularis	MH	139	D. iniquilina	PHt	Gasteromycetes	
64	Rhizopodomyces merragatae	MH	140	D. coprophila, D. crobula	PHb	Crucibulum vulgare	PHtm
65	Tetranderomyces brachidae	MH	141	Drosophila spp	PHt	Cyathus olla, C. stercorius	PHt
66	Trianderomyces bottegai	MH	142	D. semivestita	PHb	C. striatus	PHtm
	Ascomycetes: Yeasts		143	Flammula carbonaria	PHt	C. vernicosus	PH
67	Dematium chodati	PH	144	F. conissans, F. lenta	PHt	Nidula candida	PH
68	Endomycopsis ohmeri	PH	145	Fomes fraxineus	PHb	Nidularia farcta	PHt
69	Saccharomyces cerevisiae,		146	F. igniarius	PHtm	N. pisiformis	PHt
	S. ludwigii	PH	147	F. pinicola, F. roseus	PHbm	Scleroderma aurantium	PH
70	Zygosaccharomyces lactis	PH	148	Galera sphagnorum	PHt	Sphaerobolus stellatus	PHt
			149	Gloeocystidium roseo-cremum	PHb		

/1/ Amphithallic, i.e. both hetero- and homothallic spores occur in the same fruit.

109. BREEDING SYSTEMS: PLANTS

Systems listed below indicate the usual classification of breeding. Where variability exists within a species, the predominating system is enclosed in parentheses.

SC-S = species predominately self-compatible, no inbreeding degeneration; SC = self-compatible, intermediate, with perhaps a predominance of outcrossing; SC-M = self-compatible, monoecious, therefore rarely self under open pollination; SI = self-incompatible; D = dioecious; A = apomictic.

Species	System	Species	System	Species	System
Monocotyledones		Dicotyledones (continued)		Dicotyledones (continued)	
1 Pandanaceae		60 Betulaceae (concluded)		119 Rosaceae (concluded)	
2 Screw-pine (<i>Pandanus tectorius</i>)	D	61 Filbert (<i>Corylus</i> spp)	SC-M	120 Cherry (<i>Prunus avium</i>)	SI
3 Gramineae		62 Hophornbeam (<i>Ostrya virginiana</i>)	SC-M	121 Cherry (<i>P. cerasus</i>)	SC
4 Barley (<i>Hordeum sativum</i>)	SC-S	63 Fagaceae		122 Loquat (<i>Eriobotrya japonica</i>)	SC
5 Buffalo grass (<i>Buchloe dactyloides</i>)	D	64 Beech (<i>Fagus</i> spp)	SC-M	123 Medlar (<i>Mespilus germanica</i>)	SC
6 Corn (<i>Zea mays</i>)	SC-M	65 Chestnut (<i>Castanea</i> spp)	SC-M	124 Peach (<i>Prunus persica</i>)	SC
7 Fescue (<i>Festuca pratensis</i>)	SI	66 Oak (<i>Quercus</i> spp)	SC-M	125 Pear (<i>Pyrus communis</i>)	SI
8 Millet (<i>Panicum miliaceum</i>)	SC-S	67 Elm (<i>Ulmus</i> spp)	SC-M	126 Plum (<i>Prunus americana</i>)	SI
9 Oat (<i>Avena sativa</i>)	SC-S	68 Hackberry (<i>Celtis occidentalis</i>)	SC	127 Plum (<i>P. salicina</i>)	SI
10 Orchardgrass (<i>Dactylis glomerata</i>)	SI	69 Moraceae		128 Quince (<i>Cydonia oblonga</i>)	SC
11 Rice (<i>Oryza sativa</i>)	SC-S	70 Breadfruit (<i>Artocarpus incisa</i>)	SC	129 Rose (<i>Rosa</i> , most spp)	SC
12 Rye (<i>Secale cereale</i>)	SI	71 Broussonetia (<i>Broussonetia papyrifera</i>)	D	130 Rose (<i>R. rugosa</i>)	SI
13 Ryegrass (<i>Lolium perenne</i>)	SI	72 Castillo (<i>Castilleja elastica</i>)	SC	131 Rubus (<i>Rubus</i> , most spp)	SC
14 Sorghum (<i>Sorghum vulgare</i>)	SC-S	73 Chlorophora (<i>Chlorophora tinctoria</i>)	D	132 Rubus (<i>R. calvatus</i>)	A
15 Sugar cane (<i>Saccharum officinarum</i>)	SI	74 Ficus (<i>Ficus</i> , most spp)	SC	133 Rubus (<i>R. nitidoides</i>)	A
16 Teosinte (<i>Euchlaena mexicana</i>)	SC-M	75 Fig (<i>F. carica</i>)	D	134 Rubus (<i>R. thyrsiger</i>)	A
17 Timothy (<i>Phleum pratense</i>)	SC-S	76 Hemp (<i>Cannabis sativa</i>)	D	135 Strawberry (<i>Fragaria chiloensis</i>)	D
18 Wildrice (<i>Zizania aquatica</i>)	SC-M	77 Hop (<i>Humulus lupulus</i>)	D	136 Strawberry (<i>F. virginiana</i>)	D
19 Cyperaceae		78 Mulberry (<i>Morus alba</i>)	D	137 Strawberry (<i>F. viridis</i>)	SI
20 Sedge (<i>Cyperus papyrus</i>)	SC	79 Mulberry (<i>M. nigra</i>)	D	138 Leguminosae	
21 Sedge (<i>C. tegetiformis</i>)	SC	80 Osage-orange (<i>Maclura pomifera</i>)	D	139 Acacia (<i>Acacia</i> spp)	SC
22 Palmaceae		81 Proteaceae		140 Alfalfa (<i>Medicago sativa</i>)	SI
23 Date (<i>Phoenix dactylifera</i>)	D	82 Silk oak (<i>Grevillea robusta</i>)	SC	141 Bean (<i>Phaseolus aureus</i>)	SC
24 Oil palm (<i>Elaeis guineensis</i>)	SC	83 Polygonaceae		142 Bean (<i>P. lunatus</i>)	SC-S
25 Palmetto (<i>Sabal palmetto</i>)	SC	84 Buckwheat (<i>Fagopyrum esculentum</i>)	SI ³	143 Bean (<i>P. multiflorus</i>)	SC
26 Palmyra palm (<i>Borassus flabellifer</i>)	D	85 Sea-grape (<i>Coccoloba uvifera</i>)	SC	144 Bean (<i>P. vulgaris</i>)	(SC-S)
27 Wine palm (<i>Caryota urens</i>)	SC	86 Chenopodiaceae		145 Broadbean (<i>Vicia faba</i>)	SC
28 Cyclanthaceae		87 Beet (<i>Beta vulgaris</i>)	SI	146 Cassia (<i>Cassia</i> spp)	SC
29 Carludovica (<i>Carludovica palmata</i>)	SI	88 Spinach (<i>Spinacia oleracea</i>)	D	147 Clover (<i>Trifolium hybridum</i>)	SI
30 Araceae		89 Caryophyllaceae		148 Clover (<i>T. incarnatum</i>)	SI
31 Sweet flag (<i>Acorus calamus</i>)	SI	90 Bouncing-bet (<i>Saponaria officinalis</i>)	SC	149 Clover (<i>T. pratense</i>)	SI
32 Bromeliaceae		91 Carnation (<i>Dianthus caryophyllus</i>)	SC	150 Clover (<i>T. repens</i>)	SI
33 Pineapple (<i>Ananas sativus</i>)	SI	92 Berberidaceae		151 Crotalaria (<i>Crotalaria juncea</i>)	SC
34 Juncaceae		93 May apple (<i>Podophyllum peltatum</i>)	SC	152 Honeylocust (<i>Gleditsia triacanthos</i>)	SC
35 Liliaceae		94 Annonaceae		153 Hyacinth-bean (<i>Dolichos lablab</i>)	SC
36 Aloe (<i>Aloe</i> spp)	SI	95 Custard-apple (<i>Annona</i> spp)	SC	154 Ky. coffeetree (<i>Gymnocladus dioica</i>)	D
37 Asparagus (<i>Asparagus officinalis</i>)	D	96 Myristicaceae		155 Lentil (<i>Lens esculenta</i>)	SC-S
38 Chives (<i>Allium schoenoprasum</i>)	SI	97 Nutmeg (<i>Myristica fragrans</i>)	D	156 Lespedeza (<i>Lespedeza striata</i>)	SC
39 Garlic (<i>A. sativum</i>)	A	98 Lauraceae		157 Locust (<i>Robinia pseudoacacia</i>)	SC
40 Hyacinth (<i>Hyacinthus orientalis</i>)	SC	99 Avocado (<i>Persea gratissima</i>)	SC	158 Pea (<i>Pisum sativum</i>)	(SC-S)
41 Lily (<i>Lilium candidum</i>)	(SC)	100 Beberry wood (<i>Nectandra rodioei</i>)	SC	159 Peanut (<i>Arachis hypogaea</i>)	(SC-S)
42 Lily (<i>L. regale</i>)	(SC)	101 Cinnamon (<i>Cinnamomum</i> spp)	SC	160 Pigeon-pea (<i>Cajanus indicus</i>)	SC
43 Onion (<i>Allium cepa</i>)	SC ²	102 Sassafras (<i>Sassafras albidum</i>)	D	161 Soybean (<i>Glycine soja</i>)	(SC-S)
44 Shallot (<i>A. ascalonicum</i>)	SC	103 Sweet bay (<i>Laurus nobilis</i>)	D	162 Sweetpea (<i>Lathyrus odoratus</i>)	(SC-S)
45 Smilax (<i>Smilax officinalis</i>)	D	104 Papaveraceae		163 Geraniaceae	
46 Tulip (<i>Tulipa</i> spp)	SI	105 Poppy (<i>Papaver somniferum</i>)	SC	164 Geranium (<i>Pelargonium graveolens</i>)	SC
47 Yucca (<i>Yucca</i> spp)	SI	106 Poppy, prickly (<i>Argemone mexicana</i>)	SC	165 Geranium (<i>P. odoratissimum</i>)	SC
48 Amaryllidaceae		107 Capparidaceae		166 Linaceae	
49 Agave (<i>Agave</i> spp)	SI	108 Caper-bush (<i>Capparis spinosa</i>)	SC	167 Flax (<i>Linum usitatissimum</i>)	SC-S
50 Narcissus (<i>Narcissus</i> spp)	SI	109 Cruciferae		168 Erythroxylaceae	
51 Iridaceae		110 Cabbage (<i>Brassica oleracea</i>)	(SI)	169 Coca (<i>Erythroxylum coca</i>)	SI ³
52 Crocus (<i>Crocus</i> spp)	SC	111 Horse-radish (<i>Radicula armoracia</i>)	SI	170 Zygophyllaceae	
53 Iris (<i>Iris</i> spp)	SC	112 Mustard (<i>Brassica nigra</i>)	SI	171 Guaiacum (<i>Guaiacum officinale</i>)	SC
54 Dioscoreaceae		113 Mustard (<i>B. juncea</i>)	SC	172 Rutaceae	
55 Yam (<i>Dioscorea alata</i>)	SC	114 Pepper-grass (<i>Lepidium sativum</i>)	SC-S	173 Citrus (<i>Citrus</i> spp)	SC ²
56 Musaceae		115 Radish (<i>Raphanus sativus</i>)	SI	174 Torch-wood (<i>Amyris elemifera</i>)	SC
57 Abaca (<i>Musa textilis</i>)	SC	116 Rape (<i>Brassica napus</i>)	SC	175 Meliaceae	
58 Plantain (<i>M. paradisiaca</i>)	SC	117 Roquette (<i>Eruca sativa</i>)	SI	176 Mahogany (<i>Swietenia mahogany</i>)	SC
59 Zingiberaceae		118 Rutabaga (<i>Brassica campestris</i>)	SI	177 Euphorbiaceae	
60 Ginger (<i>Zingiber officinale</i>)	SI	119 Sea-kale (<i>Cakile maritima</i>)	SI	178 Castor bean (<i>Ricinus communis</i>)	SC-M
61 Cannaceae		120 Stock (<i>Matthiola incana</i>)	SC	179 Buxaceae	
62 Canna (<i>Canna edulis</i>)	SC	121 Wallflower (<i>Cheiranthus cheiri</i>)	SC	180 Boxwood (<i>Buxus sempervirens</i>)	SC-M
63 Marantaceae		122 Water-cress (<i>Radicula nasturtium-aquaticum</i>)	SC	181 Anacardiaceae	
64 Arrowroot (<i>Maranta arundinacea</i>)	SC	123 Resedaceae		182 Pistachio (<i>Pistacia cabulica</i>)	D
Dicotyledones		124 Dyer's-weed (<i>Reseda luteola</i>)	SC	183 Pistachio (<i>P. lentisous</i>)	D
65 Piperaceae		125 Mignonette (<i>R. odorata</i>)	SI	184 Pistachio (<i>P. vera</i>)	D
66 Pepper (<i>Piper</i> spp)	D	126 Saxifragaceae		185 Aquifoliaceae	
67 Salicaceae		127 Currant, gooseberry (<i>Ribes</i> spp)	SC	186 Holly (<i>Ilex</i> spp)	D
68 Poplar (<i>Populus</i> spp)	D	128 Hamamelidaceae		187 Aceraceae	
69 Willow (<i>Salix</i> spp)	D	129 Witch-hazel (<i>Hamamelis virginiana</i>)	SC	188 Maple (<i>Acer</i> spp)	SC
70 Myricaceae		130 Platanaceae		189 Rhamnaceae	
71 Wax myrtle (<i>Myrica cerifera</i>)	D	131 Sycamore (<i>Platanus occidentalis</i>)	SC-M	190 Buckthorn (<i>Rhamnus cathartica</i>)	D
72 Juglandaceae		132 Sycamore (<i>P. orientalis</i>)	SC-M	191 Buckthorn (<i>R. frangula</i>)	SC
73 Hickory (<i>Carya</i> spp)	SC-M	133 Rosaceae		192 Buckthorn (<i>R. infectoria</i>)	D
74 Walnut (<i>Juglans</i> spp)	SC-M	134 Almond (<i>Prunus communis</i>)	(SI)	193 Buckthorn (<i>R. purshiana</i>)	SC
75 Betulaceae		135 Apple (<i>Pyrus malus</i>)	SI	194 Vitaceae	
76 Alder (<i>Alnus</i> spp)	SC-M	136 Apricot (<i>Prunus armeniaca</i>)	SC	195 Grape (<i>Vitis vinifera</i>)	SC
77 Birch (<i>Betula</i> spp)	SC-M			196 Tiliaceae	
				197 Basswood (<i>Tilia</i> spp)	SC

/1/ Self-compatible, fertile by means of its own pollen; self-incompatible, sterile to its own pollen; monoecious, staminate and pistillate flowers borne on same plant; dioecious, staminate and pistillate flowers borne on separate plants; apomictic, reproduction without fertilization. /2/ Some plants apomictic. /3/ Heterostyled, i.e., stigma and stamens inserted at different levels.

109. BREEDING SYSTEMS: PLANTS (Concluded)

Systems listed below indicate the usual classification of breeding. Where variability exists within a species, the predominating system is enclosed in parentheses.

SC-S = species predominately self-compatible, no inbreeding degeneration; SC = self-compatible, intermediate, with perhaps a predominance of outcrossing; SC-M = self-compatible, monoecious, therefore rarely selfed under open pollination; SI = self-incompatible; D = dioecious; A=apomictic.

Species	System	Species	System	Species	System ¹
Dicotyledones (continued)		Dicotyledones (continued)		Dicotyledones (concluded)	
183 Malvaceae		Myrtaceae (concluded)		230 Labiatae	
184 Cotton (Gossypium spp)	SC-S	206 Guava (Psidium guajava)	SC	231 Catnip (Nepeta cataria)	SC
Hibiscus (Hibiscus cannabinus)	SC	207 Pimento (Pimenta officinalis)	SC	232 Lavender (Lavandula officinalis)	SC
Bombacaceae		208 Rose-apple (Eugenia jambos)	SI	233 Marjoram (Origanum majoram)	SC
185 Baobab (Adansonia digitata)	SC	Umbelliferae		234 Mint (Mentha spp)	SC
186 Durian (Durio zibethinus)	SC	209 Angelica (Angelica archangelica)	SC	235 Sage (Salvia officinalis)	SC
187 Silk-cotton tree (Bombax ceiba)	SI	210 Caraway (Carum carvi)	SC	236 Thyme (Thymus vulgaris)	SC
188 Silk-cotton tree (Ceiba casearia)	SC	211 Carrot (Daucus carota)	SC	Solanaceae	
Sterculiaceae		212 Celery (Apium graveolens)	SC	237 Belladonna (Atropa belladonna)	SC
189 Cacao (Theobroma cacao)	SI	213 Parsley (Petroselinum hortense)	SC	238 Eggplant (Solanum melongena)	SC
190 Sterculia (Sterculia urens)	SC	214 Parsnip (Pastinaca sativa)	SC	239 Pepper (Capsicum frutescens)	SC
Dilleniaceae		Ericaceae		240 Potato (Solanum tuberosum)	SC
191 Actinidia (Actinidia chinensis)	D	215 Vaccinium (Vaccinium spp)	SC	241 Thorn-apple (Datura stramonium)	SC
Theaceae		Sapotaceae		242 Tobacco (Nicotiana rustica)	SC
192 Camellia (Camellia sasanqua)	SC	216 Mimosa (Mimosa balata)	SC	243 Tobacco (N. tabacum)	SC
193 Tea (Thea sinensis)	SC	217 Sapodilla (Achras zapota)	SC	244 Tomato (Lycopersicon esculentum)	SC
Guttiferae		Ebenaceae		Scrophulariaceae	
194 Mangosteen (Garcinia mangostana)	A	218 Persimmon (Diospyros ebenum)	D	245 Foxglove (Digitalis purpurea)	SC
Bixaceae		219 Persimmon (D. kaki)	D	Bignoniaceae	
195 Anatto-tree (Bixa orellana)	SC	220 Persimmon (D. virginiana)	D	246 Catalpa (Catalpa speciosa)	SC
196 Cochlospermum (Cochlospermum gossypium)	SC	Oleaceae		Rubiaceae	
221 Ash (Fraxinus spp)	SC	222 Olive (Olea europaea)	SC	247 Cinchona (Cinchona spp)	SI
222 Coffee (Coffea liberica)	SC	Loganiaceae		248 Valeriana (Valeriana officinalis)	SC
197 Violet (Viola odorata)	SC	223 Strychnos (Strychnos nux-vomica)	SC	Cucurbitaceae	
198 Passion-flower (Passiflora edulis)	SC	Gentianaceae		249 Cultivated spp	SC-M
199 Passion-flower (P. ligularis)	SI	224 Gentian (Gentiana lutea)	SC	Compositae	
200 Passion-flower (P. quadrangularis)	SI	Apocynaceae		250 Artichoke (Helianthus tuberosus)	SI
225 Funtumia (Funtumia elastica)	SC	226 Strophanthus (Strophanthus spp)	SC	251 Chicory (Cichorium intybus)	SI
201 Papaya (Carica papaya)	D	Convolvulaceae		252 Dahlia (Dahlia pinnata)	SI
202 Pomegranate (Punica granatum)	SC	227 Sweetpotato (Ipomoea batatas)	SI	253 Dandelion (Taraxacum, some spp)	A
Lecythidaceae		Boraginaceae		254 Dandelion (T. kok-saghyz)	SC
203 Brazil-nut (Bertholletia excelsa)	SC	228 Borage (Borago officinalis)	SI	255 Endive (Cichorium endivia)	SC
204 Lecythis (Lecythis zabucajo)	SC	Verbenaceae		256 Guayule (Parthenium arenatum)	SI ²
Myrtaceae		229 Teak (Tectona grandis)	SC	257 Sunflower (Helianthus annuus)	SI
205 Eucalyptus spp	SC				

/1/ Self-compatible, fertile by means of its own pollen; self-incompatible, sterile to its own pollen; monoecious, staminate and pistillate flowers borne on same plant; dioecious, staminate and pistillate flowers born on separate plants; apomictic, reproduction without fertilization. /2/ Some plants apomictic.

110. EJECTION OF SPORES: FUNGI

Part I: SPORE DISPERSAL: DISTANCE EJECTED

Species	Distance Ejected	
	Horizontal mm	Vertical mm
1 Aleuria vesiculosa	10-25	10-20
2 Ascobolus immersus	300	350
3 Auricularia mesenterica	0.4-0.5	
4 Basidiobolus ranarum	10-20	
5 Coleosporium campanulae, C. petasiditis	0.6-0.9	0.3
6 Conidiobolus villosus	40	
7 Coprinus atramentarius	0.05	
8 C. curtus, C. niveus	0.1-0.2	
9 Cyathus pallidus		900-1200
10 Dacryomyces delinquescent	0.5-0.7	
11 Empusa muscae	20-30	
12 Endophyllum euphorbiae-sylvaticae ¹	0.4-0.5	
13 Endothia parasitica	90	22
14 Exidia alba	0.4	
15 Geoglossum hirsutum	5	
16 Gymnosporangium juniperi-virginianae ¹		0.3-0.4
17 Hypomyces lactifluorum		10
18 Pilobolus kleinii	2450	1840
19 P. longipes	2630	1840
20 Podospora curvicolle		>260-450
21 Puccinia spp, basidiospores ²	0.6	0.3
22 P. graminis, aeciospores		7-8
23 P. pulverulenta, aeciospores		4-5
24 Sclerospora philippinensis, S. spontanea	1-2	
25 Sordaria fimicola		60-150
26 Sphaerobolus iowensis	5050	4000
27 S. stellatus	5660	4500
28 Tilletia tritici	1.4	0.5-1
29 Urnula geaster		20-30
30 Uromyces poae, aeciospores		9
31 U. pisi, aeciospores	15-20	15-20

/1/ Data applicable to basidiospores. /2/ Species include: P. annularis, P. arenariae, P. glechomatidis, P. malvacearum.

Part II: SPORE DISPERSAL: SPECIAL FEATURES

PART II. SPORE DISPERSAL: SPECIAL FEATURES			SPECIAL FEATURES			
	Species	Projectile Size	Initial Velocity m/sec	Mechanism Analogue	Spore-fall Period	Principal Mechanism of Dispersal
1	Ascobolus immersus	35-45µ x 55-65µ	10	Squirt-gun	Diurnal	Osmotic pressure in epiplasm of ascus plus elastic contractility of ascus wall.
2	Coprinus atramentarius	5.5µ x 10µ	0.04	Ballon-gun	Continuous ¹	Excretion of small drop of water at spore hilum.
3	Pilobolus longipes	0.5 mm (dia)	14	Squirt-gun	Diurnal	Osmotic pressure in subsporangial swelling, plus elastic contractility of sporangium wall.
4	Sphaerobolus stellatus	1-1.3 mm (dia)	9	Sling-shot	Diurnal	Eversion of peridial layer by increase in osmotic pressure.
	Species	Special Feature of Projectile	Accessory Features in Dispersal	Tropistic Responses		
1	Ascobolus immersus	Gelatinous envelope covers 8-ascospore cluster.	Asci protrude from paraphyses which hold bases of asci in position.	Positive heliotropism of apothecium and asci.		
2	Coprinus atramentarius	Spores describe a curved trajectory in falling, known as a "sporabola."	Cystidia hold gills apart; autodigestion clears cystidia and gills before spore-fall.	Negative geotropism of stipe.		
3	Pilobolus longipes	Non-wettable sporangial wall basally ringed with wettable gelatin.	Ocellus-like subsporangial swelling; light orients sporangiphore.	Positive heliotropism of sporangiphore and subsporangial swelling		
4	Sphaerobolus stellatus	Glebal mass adhesive because of high fat content.	Air spaces between tooth-sinuses prevent formation of vacuum.	Positive heliotropism of fruit-body.		

/1/ For 24-48 hr.

III. PROPAGATION: CULTIVATED PLANTS

Methods listed, accompanied by preferred calendar periods, represent those widely used for the genera, but are not intended to indicate that all species of the genera can be propagated satisfactorily by each method. Horticultural varieties are not propagated by seeds, as the new plants (from seed) may vary considerably from the parent plants.

Species	Method ¹	Time	Species	Method ¹	Time
Fruit and Nut Crops			Trees and Shrubs: Broadleaf (concluded)		
1 Almond (<i>Prunus communis</i>)	Shield bud	Summer	40 Elaeagnus (<i>Elaeagnus</i> spp)	Seed	Fall or spring
2 Apple (<i>Pyrus malus</i>)	Whip graft	Winter		Semi-hardwood cutting	Late summer
3 Avocado (<i>Persea americana</i>)	Shield bud	Spring-summer		Hardwood cutting	Fall-winter
	Patch bud	Spring		Simple layering	Spring-summer
4 Blackberry (<i>Rubus</i> spp)	Whip graft	Winter	41 Hawthorn (<i>Crataegus</i> spp)	Mound layering	Spring
	Shoot	Spring		Seed	Fall or winter
	Root cutting	Late winter		Whip graft	Spring
5 Blueberry (<i>Vaccinium corymbosum</i>)	Hardwood cutting	Early spring		Shield bud	Summer
6 Cherry (<i>Prunus</i> spp)	Softwood cutting	Early summer		Simple layering	Spring
7 Citrus crops (<i>Citrus</i> spp)	Shield bud	Summer	42 Holly (<i>Ilex</i> spp)	Air layering	Spring
8 Cranberry (<i>Vaccinium macrocarpum</i>)	Inverted-T bud	Spring-summer		Semi-hardwood cutting	Summer
9 Dewberry (<i>Rubus</i> spp)	Hardwood cutting	Fall		Side graft	Spring
10 Fig (<i>Ficus carica</i>)	Tip layering	Summer-fall		Shield bud	Spring
	Hardwood cutting	Winter-spring		Simple layering	Spring-summer
11 Grape (<i>Vitis</i> spp)	Simple layering	Winter	43 Lilac (<i>Syringa</i> spp)	Air-layering	Spring
	Hardwood cutting	Winter		Softwood cutting	Early summer
	Whip graft	Late winter		Wedge graft	Winter
	Chip bud	Spring		Simple layering	Early spring
12 Hickory (<i>Carya</i> spp)	Veneer graft	Winter-spring	44 Magnolia (<i>Magnolia</i> spp)	Air layering	Early spring
13 Peach (<i>Prunus persica</i>)	Shield bud	June-summer		Seed	Fall
14 Pear (<i>Pyrus communis</i>)	Whip graft	Winter		Softwood cutting	Late spring
	Shield bud	Summer		Semi-hardwood cutting	Fall
15 Pecan (<i>Carya illinoensis</i>)	Patch bud	Spring		Side graft	Summer
16 Plum (<i>Prunus</i> spp)	Top graft	Winter	45 Maple (<i>Acer</i> spp)	Air layering	Spring
	Shield bud	Spring-summer		Seed	Fall
17 Raspberry (<i>Rubus occidentalis</i>)	Tip layering	Late summer		Hardwood cutting	Winter
18 Raspberry (<i>R. strigosus</i>)	Shoots	Fall-spring		Side graft	Winter
	Root cutting	Fall	46 Mockorange (<i>Philadelphus</i> spp)	Air layering	Spring
19 Strawberry (<i>Fragaria</i> spp)	Runners	Summer-fall		Shield bud	Summer
20 Walnut (<i>Juglans</i> spp)	Veneer graft	Late winter	47 Oak (<i>Quercus</i> spp)	Softwood cutting	Late spring
	Patch bud	Spring-summer		Hardwood cutting	Winter
Herbaceous Perennials			48 Poplar (<i>Populus</i> spp)	Seed	Early spring
21 Begonia (<i>Begonia</i> spp)	Softwood cutting	Year-round		Hardwood cutting	Fall
22 Caladium (<i>Caladium</i> spp)	Leaf cutting	Year-round		Root graft	Early winter
23 Carnation (<i>Dianthus caryophyllus</i>)	Tuber division	Spring	49 Privet (<i>Ligustrum</i> spp)	Air layering	Early spring
24 Chrysanthemum (<i>Chrysanthemum</i> spp)	Softwood cutting	Spring-summer		Softwood cutting	Late spring
25 Coleus (<i>Coleus blumei</i>)	Softwood cutting	Year-round		Hardwood cutting	Late summer
26 Dahlia (<i>Dahlia</i> spp)	Softwood cutting	Spring	50 Rhododendron (<i>Rhododendron</i> spp)	Simple layering	Spring-summer
	Leaf-bed cutting	Spring		Seed	Spring
	Root division	Spring		Semi-hardwood cutting	Mid-summer
27 Gladiolus (<i>Gladiolus hortulanus</i>)	Cormels	Fall		Saddle graft	Winter
	Corm division	Spring		Veneer graft	Winter
28 Hyacinth (<i>Hyacinthus orientalis</i>)	Scooping bulb	Summer	51 Rose (<i>Rosa</i> spp)	Simple layering	Spring
	Notching bulb	Summer		Air layering	Spring
29 Iris (<i>Iris germanica</i>)	Rhizome division	Fall		Semi-hardwood cutting	Late spring
30 Peony (<i>Paeonia</i> spp)	Division	Fall		Splice graft	Spring
Trees and Shrubs: Broadleaf				Shield bud	Spring-summer
31 Abelia (<i>Abelia grandiflora</i>)	Softwood cutting	Summer	52 Viburnum (<i>Viburnum</i> spp)	Air layering	Spring-summer
	Hardwood cutting	Fall		Seed	Spring
	Simple layering	Spring-summer		Softwood cutting	Late spring
32 Alder (<i>Alnus</i> spp)	Mound layering	Spring		Semi-hardwood cutting	Summer
	Seed	Fall		Side graft	Summer
	Hardwood cutting	Winter		Simple layering	Spring-summer
33 Barberry (<i>Berberis</i> spp)	Whip graft	Winter	Trees and Shrubs: Conifers		
	Seed	Fall or spring	53 Arborvitae (<i>Thuja</i> spp)	Seed	Fall or spring
	Semi-hardwood cutting	Summer		Semi-hardwood cutting	Summer
34 Basswood (<i>Tilia</i> spp)	Hardwood cutting	Fall-winter		Hardwood cutting	Fall-winter
	Seed	Fall or spring	54 Cypress (<i>Cupressus</i> spp)	Side or veneer graft	Fall-winter
	Whip graft	Early spring		Seed	Fall or spring
	Simple layering	Spring		Semi-hardwood cutting	Summer
	Air layering	Early spring	55 Douglas fir (<i>Pseudotsuga</i> spp)	Veneer graft	Summer
35 Birch (<i>Betula</i> spp)	Seed	Fall	56 Fir (<i>Abies</i> spp)	Seed	Fall or spring
	Cleft graft	Early spring		Veneer graft	Winter
	Air layering	Spring	57 Hemlock (<i>Tsuga</i> spp)	Seed	Fall or spring
36 Boxwood (<i>Buxus</i> spp)	Semi-hardwood cutting	Summer		Side or veneer graft	Spring
	Hardwood cutting	Fall-winter		Semi-hardwood cutting	Summer
	Simple layering	Spring-summer	58 Juniper (<i>Juniperus</i> spp)	Air layering	Early spring
37 Camellia (<i>Camellia</i> spp)	Semi-hardwood cutting	Spring-summer		Seed	Fall or spring
	Air layering	Spring		Side graft	Winter
38 Cotoneaster (<i>Cotoneaster</i> spp)	Seed	Fall or spring		Hardwood cutting	Winter
	Semi-hardwood cutting	Summer	59 Pine (<i>Pinus</i> spp)	Seed	Fall or spring
	Root graft	Early winter		Veneer graft	Winter-spring
39 Dogwood (<i>Cornus</i> spp)	Seed	Fall or spring		Air layering	Spring-fall
	Semi-hardwood cutting	Early summer	60 Spruce (<i>Picea</i> spp)	Seed	Fall or spring
	Hardwood cutting	Summer		Semi-hardwood cutting	Summer
	Simple layering	Spring		Veneer graft	Fall-winter
	Air layering	Spring	61 Yew (<i>Taxus</i> spp)	Seed	Fall or spring
				Hardwood cutting	Fall-winter
				Air layering	Spring

/1/ Propagation by seed may involve pretreatment. Seeds of those species having no apparent rest period may be sown in spring, those having a definite rest period should be artificially stratified or sown in fall. /2/ To be sown as soon as mature.

112. SEED PRODUCTION, DORMANCY, AND GERMINATION: FOREST TREES

Species	Seed-Bearing Age ¹ yr	Fre- quency yr	Weight of 1000 Seeds ² g	Dormancy Type ³	Germination				
					Duration, da		Sprouting, % ⁴		
					Untreated	Pretreated	In Lab	In Field	
Broadleaf Trees									
1 Alder (<i>Alnus rubra</i>)	10-100	3-5	0.7(0.4-1.2)	Embryo?	60	30-40	27	14	
2 Ash (<i>Fraxinus americana</i>)	20-175	3-5	45(25-82)	Embryo	>60	40-60	38	20	
3 Ash (<i>F. pennsylvanica</i>)	20-	1-3	26(18-41)	Embryo	60->90	40-60	42	20	
4 Aspen (<i>Populus tremuloides</i>)	20->70	4-5	0.1	None	7		59	50	
5 Basswood (<i>Tilia americana</i>)	15->100	1-3	91(57-151)	Embryo + seed coat	200-1000	30-60	34	20	
6 Beech (<i>Fagus grandifolia</i>)	40-100	2-3	284(197-349)	Embryo	150-160	60	85	40	
7 Birch (<i>Betula lenta</i>)	40-	1-2	0.7(0.5-0.9)	Embryo?	90	30	43	15	
8 Birch (<i>B. alleghaniensis</i>)		1-2	1(0.5-1.6)	Embryo?	>120	30-40	27	15	
9 Birch (<i>B. papyrifera</i>)	15->70	1-3	0.3(0.1-0.7)	Embryo?	>100	30-40	34	15	
10 Butternut (<i>Juglans cinerea</i>)	20-80	2-3	15, 120(11, 340-30, 240)	Embryo + seed coat?	>110	45-60	65	50	
11 Catalpa (<i>Catalpa speciosa</i>)	20-	2-4	22(15-28)	None?	60		75	70	
12 Cherry (<i>Prunus serotina</i>)	10-125	1-3	94(56-146)	Embryo + seed coat?	>190	30	63	30	
13 Chestnut (<i>Castanea dentata</i>)	20->150	2-3	3489(2835-4536)	Embryo	100	30-45	72	55	
14 Coffeetree (<i>Gymnocladus dioica</i>)	20->100	1-2	1649(1243-2160)	Seed coat	200	60-90	75	50	
15 Cottonwood (<i>Populus deltoides</i>)	10-death	1-3	1(0.8-2.3)	None	2-6		88	80	
16 Elm (<i>Ulmus americana</i>)	15-300	1-3	6.7(4.8-9.4)	Embryo (variable)	90	15-60	63	15	
17 Elm (<i>U. rubra</i>)	15-200	2-4	11.1(8.4-13)	Embryo ⁵	90->120	50-70	17	10	
18 Hackberry (<i>Celtis occidentalis</i>)		1-3	105(84-130)	Embryo + seed coat?	60-100	60	41	20	
19 Hickory (<i>Carya glabra</i>)	30-300	1-2	2268(2016-2592)	Embryo	250-300	30-45	85	40	
20 Hickory (<i>C. ovata</i>)	40-300	1-3	4536(3024-5670)	Embryo	300-350	45-60	80	55	
21 Hickory (<i>C. tomentosa</i>)	25-200	2-3	5040(4, 014-13, 341)	Embryo	300-350	45-60	66	65	
22 Honeylocust (<i>Gleditsia triacanthos</i>)	10-100	1-2	162(112-259)	Seed coat	120-180	15-40	50	50	
23 Locust (<i>Robinia pseudoacacia</i>)	6-60	1-2	19(13-28)	Seed coat	40-70	10-25	68	25	
24 Maple (<i>Acer rubrum</i>)		1-3	20(12-36)	Embryo (variable)	>90	30-40	46	58	
25 Maple (<i>A. saccharinum</i>)	35-	1-3	324(239-504)	None	20-30		76	18	
26 Maple (<i>A. saccharum</i>)	to >200	3-7	74(50-142)	Embryo	>150	30	39	15	
27 Oak (<i>Quercus alba</i>)	20-300	4-10	3024(2160-6480)	None	30-50		78	66	
28 Oak (<i>Q. coccinea</i>)	20-150	Irregular	1620(1120-2926)	Embryo	>240	60	62	60	
29 Oak (<i>Q. falcata</i>)	25-125	1-2	762(578-1163)	Embryo	>240	30-40	<90	65	
30 Oak (<i>Q. rubra</i>)	25-200	2-3	3240(1779-5670)	Embryo	>300	40-60	58	70	
31 Oak (<i>Q. velutina</i>)	20-100	2-3	1814(1134-3629)	Embryo	>240	30-50	47	>50	
32 Pecan (<i>Carya illinoensis</i>)	20-300	1-2	4536(2835-8247)	Embryo	200-300	45-60	50	50	
33 Sweetgum (<i>Liquidambar styraciflua</i>)	20-150	1-3	6(5-7)	Embryo?	120-200	20-60	70	50	
34 Sycamore (<i>Platanus occidentalis</i>)	25-250	1-2	2.2(2-3)	Embryo?	30-60	15-20	35	20	
35 Tupelo (<i>Nyssa sylvatica</i>)			137(113-245)	Embryo	>150	30-60	30	20	
36 Walnut (<i>Juglans nigra</i>)	12-	Irregular	11, 340(4, 536-22, 680)	Embryo + seed coat	100-300	15-40	75	55	
37 Yellow-poplar (<i>Liriodendron tulipifera</i>)	15->200	Irregular	32(19-45)	Embryo + seed coat?	90-180	50-70	5	3	
Conifers									
38 Alaska-cedar (<i>Chamaecyparis nootkatensis</i>)	15-300	Occasional	4.2(2.5-6.9)	Embryo?	>300	60	10	5	
39 Baldcypress (<i>Taxodium distichum</i>)		3-5	95(50-349)	Embryo, + seed coat?	60-110	30-50	12	8	
40 Cypress (<i>Cupressus arizonica</i>)		1-3	11.3(6.7-16.8)	Embryo?	75	30	26	15	
41 Douglas-fir (<i>Pseudotsuga menziesii</i>)	15-600	3-5	10.8(6.7-22.7)	Embryo + seed coat ⁶	60-90	15-30	85	55	
42 Fir (<i>Abies amabilis</i>)	30-300	2-3	40(30-55)	Embryo (variable)	100	30	22	15	
43 Fir (<i>A. balsamea</i>)	20->60	2-4	7.6(4.8-15.1)	Embryo (variable)	210	60-120	22	15	
44 Fir (<i>A. concolor</i>)	40-200	3-5	30(17-55)	Embryo (variable)	>100	30	34	15	
45 Fir (<i>A. grandis</i>)	20-300	2-3	20(10-36)	Embryo? (variable)	100	30	28	15	
46 Fir (<i>A. magnifica</i>)	50->200	2-3	69(41-113)	Embryo (variable)	>100	30-45	25	15	
47 Fir (<i>A. procera</i>)	30-300	Infrequent	31(24-40)	Embryo (variable)	100	30	24	15	
48 Hemlock (<i>Tsuga canadensis</i>)	30->400	2-3	2.4(1.3-3.4)	Embryo (variable)	200	60	38	20	
49 Hemlock (<i>T. heterophylla</i>)	25-300	2-5	1.5(0.9-2.1)	Embryo (variable)	>90	30	56	30	
50 Incense-cedar (<i>Libocedrus decurrens</i>)	20->200	3	30(16-71)	Embryo? (variable)	>60	20-30	50	25	
51 Juniper (<i>Juniperus scopulorum</i>)	10-300	2-5	16(11-25)	Embryo + seed coat	>200	20-30	22	20	
52 Larch (<i>Larix occidentalis</i>)	40->60	5-6	3.2(2.3-4.6)	Embryo? (variable)	60	20-30	27	20	
53 Pine (<i>Pinus banksiana</i>)	5->80	3-4	3.4(1.8-6.4)	Embryo (occasional)	15-60		68	45	
54 Pine (<i>P. echinata</i>)	16->280	5-10	9.4(7.3-12.4)	Embryo?	60-120	35-45	68	35	
55 Pine (<i>P. elliotii</i>)	12->150	1-10	31(28-35)	Embryo? (occasional)	45	20-40	61	30	
56 Pine (<i>P. jeffreyi</i>)	8->150	2-4	113(84-146)	Embryo (occasional)	60-90		68	50	
57 Pine (<i>P. lambertiana</i>)	40-300	3-5	216(142-302)	Embryo? (variable)	120	40	56	35	
58 Pine (<i>P. monticola</i>)	15-300	4-6	17(14-32)	Embryo? + seed coat ⁶	200	60-90	48	30	
59 Pine (<i>P. palustris</i>)	20->350	3-7	108(76-119)	Embryo? (rare)	30-40	35	54	35	
60 Pine (<i>P. ponderosa</i>)	20-300	2-5	38(20-66)	Embryo? (occasional)	60	30	59	45	
61 Pine (<i>P. resinosa</i>)	25->200	3-7	8.7(6.4-15.1)	None	30		75	55	
62 Pine (<i>P. strobus</i>)	15-250	3-5	16.8(8.6-22.7)	Embryo	60-100	30-40	64	50	
63 Pine (<i>P. taeda</i>)	12->60	3-10	25(18-28)	Embryo?	70	35-45	60	30	
64 Port-Orford-cedar (<i>Chamaecyparis lawsoniana</i>)	8-200	4-5	2.2(0.8-5.7)	Embryo?	60-110	60	52	25	
65 Redcedar (<i>Juniperus virginiana</i>)	10-175	2-3	10(8-26)	Embryo + seed coat	>180	20-30	42	30	
66 Redcedar (<i>Thuja plicata</i>)	16->200	2-5	1.1(0.9-2.2)	Embryo (variable)	40	20	51	35	
67 Redwood (<i>Sequoia sempervirens</i>)	20->300	1-3	3.7(1.5-7.7)	Embryo? (variable)	40-60		10	5	
68 Sequoia (<i>S. gigantea</i>)	125->300	1-3	5(3.4-8.4)	Embryo? (variable)	40-60		25	15	
69 Spruce (<i>Picea engelmannii</i>)	16->200	2-3	3.4(2.3-6.6)	Embryo (occasional)	50		69	45	
70 Spruce (<i>P. glauca</i>)	30-	2-6	1.9(1.1-3.2)	Embryo	50-140	30-45	50	35	
71 Spruce (<i>P. mariana</i>)	30-250	4-5	1.1(0.9-1.4)	Embryo	30-80	20-30	64	40	
72 Spruce (<i>P. rubens</i>)	30-	3-8	3.2(1.6-4.5)	Embryo	30-50	20-30	60	40	
73 Spruce (<i>P. sitchensis</i>)	25-300	3-4	2.2(1.1-2.9)	Embryo (variable)	60	50	60	40	
74 White-cedar (<i>Chamaecyparis thyoides</i>)	4->100	1-3	1.0(0.9-1.1)	Embryo?	60-110	60	84	40	
75 White-cedar (<i>Thuja occidentalis</i>)	30->100	5	1.3(0.8-2.5)	Embryo (variable)	50	30	46	30	

/1/ Age of most abundant production. /2/ Cleaned. /3/ Dormancy may be general, variable (dormant and non-dormant seeds in same sample), occasional, or rare. Type is general unless otherwise indicated. /4/ Great variation reported. /5/ Northern sources only. /6/ Variable.

113. PHENOLOGICAL VALUES: FOREST TREES, U. S. A.

Within a species there is variation in time of growth expressions, depending upon such factors as latitude, altitude, slope, distribution of rainfall, and earliness or lateness of growing season. Many species have a broad distribution. Growth-period values are averages. Dates of stages where the growing season is short are enclosed in parentheses; dates of stages not so enclosed are for the long growing season. When the month is followed by I, growth stage occurs during first 10 days of the month; by II, during second 10 days; by III, during last 10 days. When no number appears after the month, growth stage occurs during the entire month. Species indicated by an asterisk (*) are evergreen; all other species are deciduous.

Species	Leafing	Leaf Falling	Flowering ¹	Seed Maturing	Seed Falling	Height Growth	Diameter Growth
Eastern United States							
1 Ash, black (<i>Fraxinus nigra</i>)	May III-June III	Sept III-Oct I	May III	July II-Aug III	July III-Oct III ⁺	May III-July II	May III-Sept I
2 Ash, green (<i>F. pennsylvanica</i>)	Apr (Apr III-June I)	(Sept II-Oct I)	Apr II-Apr III (Apr III-May I)			(Apr III-July II)	(Apr II-July III)
3 Ash, white (<i>F. americana</i>)	Apr II-Apr III (May III-June I)	Oct I-Nov I (Sept III-Oct I)	Apr I-May I (May I-May II)	(To Aug III)	(Sept I-Oct III)	(May III-June III)	(May II-July III)
4 Aspen, bigtooth (<i>Populus grandidentata</i>)	Apr II-May I (May III-June II)	Oct I-Oct II (Oct I-Oct II)	Apr I-Apr II (Apr III-May I)	Apr III (May II)	May I-May II (May III-June I)		
5 Baldcypress (<i>Taxodium distichum</i>)	Mar II-Apr II	Oct III-Nov III	Mar I-Apr II	Oct I-Oct II	Oct III-Dec III ²		
6 Basswood, American (<i>Tilia americana</i>)	Apr III-May I (May III-)	Oct I-Nov I (Sept III-Oct I)	June (July III)	Aug (Aug III)	Sept I-Oct II ⁺ (Sept)	Apr III-June II	June II-Sept II
7 Beech, American (<i>Fagus grandifolia</i>)	Mar (May III-June I)	Nov I-Dec II (Oct)	Apr I-Apr II (June)	To Sept II (To Sept I)	Sept III-Nov I (Oct II-)		(Apr II-July I)
8 Birch, gray (<i>Betula populifolia</i>)	Apr III-May II (Apr III-May I)	Oct (Oct)	Apr III-May II (Apr III-May I)	Sept III To July III	Oct I-Nov III ⁺ Aug I - (Oct)		May III-Aug I
9 Birch, paper (<i>B. papyrifera</i>)	Apr III-May I (May III-June I)	Oct (Sept III-Oct II)	Apr III-May I (June I)	To July III (Sept II-Sept III)	Aug I - (Oct)		
10 Birch, sweet (<i>B. lenta</i>)	Apr II-May III	Oct	Apr I-May I	Aug III-Sept I	Sept II-Oct III ⁺		
11 Birch, yellow (<i>B. allegheniensis</i>)	Apr III-May I (May II-June I)	Oct II-Oct III (Sept III-Oct II)	Apr III (May II)	Aug I (Aug II)	Aug II-Oct III ⁺ (Sept III-)	(May III-Aug I)	(June II-Aug I)
12 Buckeye, Ohio (<i>Aesculus glabra</i>)	Mar III-May I	Oct	Mar III-May II	To Sept II	Sept III-Oct II		
13 Butternut (<i>Juglans cinerea</i>)	Apr II-May II	Sept II-Oct II	Apr II-May II	Sept III	Oct I-Nov II		
14 Cherry, black (<i>Prunus serotina</i>)	Mar III-Apr II (May II-June I)	Oct II-Nov I (Sept III-Oct I)	Apr (June I)	To June III (Aug II)	July I-Aug III ⁺ (Sept I-)	Mar II-June III	May III-Sept III
15 Chestnut (<i>Castanea dentata</i>)	Apr III-May II	Oct II-Nov III	June III-July I	Sept III-Oct I	Oct II-Nov III		
16 Cottonwood, eastern (<i>Populus deltoides</i>)	Mar II-Apr I (May I-May II)	Oct II-Nov I (Sept II-Oct II)	Mar I-Mar II (Apr III-May I)	Apr I (May II-May III)	Apr II-Apr III (May III-June III)		
17 Dogwood, flowering (<i>Cornus florida</i>)	Mar III-Apr II (May I-May II)	Oct I-Nov I (Oct I-Oct II)	Mar III-Apr II (May I-May II)	To Oct III (Sept III)	Nov (Oct II-Nov III)		Apr II-July I
18 Elm, American (<i>Ulmus americana</i>)	Mar III-Apr I (May III-June I)	Oct I-Nov I (Oct I-Oct II)	Feb I-Mar I (May II-May III)	Mar II-Mar III (June II)	Apr (July III-)		(May II-Aug I)
19 Elm, rock (<i>U. thomasi</i>)	Apr II-May I	Sept III-Oct II	Apr	May II	May III-July I		
20 Elm slippery (<i>U. rubra</i>)	Mar III-Apr I (Apr III-May II)	Oct (Sept III-Oct II)	Feb III-Mar I (Apr II-Apr III)	Apr I (May II)	Apr II-Apr III (May III-June I)		(Apr III-Aug III)
21 Elm, winged (<i>U. alata</i>)	Mar III-Apr II		Feb I- Mar I	Apr I-Apr II	Apr III-		Apr III-July II
22 Fir, balsam (<i>Abies balsamea</i>)*	May III-June I	Sept III-Oct II	May II-May III	Aug III-Sept I	Sept II-Nov III	May III-Aug II	May III-Sept I
23 Hemlock, eastern (<i>Tsuga canadensis</i>)*	May III-June II	Sept II-Oct III	May II-June I	Sept I-Oct II	Oct III-Apr III ²	May III-Aug II	
24 Hickory, mockernut (<i>Carya tomentosa</i>)	Apr	Oct	Apr II-May I	To Sept III	Oct ⁺		Apr I-July II
25 Hickory, pignut (<i>C. glabra</i>)	Apr (May I-May II)	Oct I-Nov I Oct	Apr II-May I (May II-May III)	To Oct I (To Sept III)	Oct I-Nov I ⁺		
26 Hickory, shagbark (<i>C. ovata</i>)	Apr I-May I	Oct	Apr II-May III	Sept II-Sept III	Oct I-Nov I ⁺		
27 Holly, American (<i>Ilex opaca</i>)*	Apr I-May I	Mar	Apr II-June I	Sept II-Oct II	Mar		
28 Locust, black (<i>Robinia pseudoacacia</i>)	Apr I-May I	Sept III-Oct III	Apr III-May III	Sept II-Oct I	Oct II-Dec III ²		
29 Maple, red (<i>Acer rubrum</i>)	Mar I-Apr II (May II-June I)	Oct III-Nov I (Sept III-Oct I)	Jan II-Jan III (May)	To Mar II (To June III)	Mar III-Apr II (July I)		May I-July II
30 Maple, silver (<i>A. saccharinum</i>)	Feb III-May II (Apr II-May I)	Oct III-Nov I (Oct II-Oct III)	Feb I-Mar I (Mar III-Apr II)	To Mar III (May I-May II)	Apr (May III-June I)	(May I-July III)	
31 Maple, sugar (<i>A. saccharum</i>)	Apr III-May I (May III-June I)	Oct I-Nov I (Sept III-Oct I)	Apr III-May I (May II-May III)	Aug I-Sept III (to Sept II) (Aug I)	Sept III-Oct III ⁺ (Sept I-)	(Apr II-July III)	(Apr III-Aug III)
32 Mulberry, red (<i>Morus rubra</i>)	Apr	Oct	Apr II-May II	June	July I-Aug III	Apr II-May III (May II-Aug III)	June II-Aug III (June I-Sept I)
33 Oak, black (<i>Quercus velutina</i>)	Apr III-May III	Oct III-Nov III	Apr III-May II	Sept	Oct I-Nov I		
34 Oak, bur (<i>Q. macrocarpa</i>)	Apr (May II-May III)	Oct III-Nov II (Sept III-Oct II)	Apr III-May I (June I-June II)	Sept II-Sept III (Sept I-Sept II)	Oct (Sept III-Nov I)		Apr II-July III
35 Oak, northern red (<i>Q. rubra</i>)	Apr II-May I (May III-June I)	Oct III-Nov I (Oct I-Oct II)	Apr III-May I (May III-June I)	Sept I-Sept II (Sept I)	Sept III-Nov I (Sept II)	(May III-June II)	
36 Oak, post (<i>Q. stellata</i>)	Apr (May I-May II)	Oct II-Nov I (Oct II-)	Apr II (May II)	Sept III-Oct I	Oct II-Nov I (Oct I)		Apr I-July I
37 Oak, scarlet (<i>Q. coccinea</i>)	Apr III-May II	Oct II-	Apr III-May I	Sept	Oct		
38 Oak, southern red (<i>Q. falcata</i>)	Apr		Apr I-May I	Sept	Oct		Apr I-July I
39 Oak, white (<i>Q. alba</i>)	Mar III-Apr II (May II-June I)	Oct III-May I (Oct II-Oct III)	Apr I-Apr II (May II)	Sept III-Oct I (Sept II-Sept III)	Oct II-Nov I (Sept III-)	Mar III-July III	
40 Pine, eastern white (<i>Pinus strobus</i>)*	May I-Aug I (May III-Aug II)	Sept I-Oct II (Sept II-Sept III)	May II-June I (June III)	Aug I-Sept III (Sept I-Sept II)	Oct (Sept II-Oct III)	Apr III-June III (May III-Aug I)	Apr III-Sept III (May I-Sept III)
41 Pine, jack (<i>P. banksiana</i>)*	May III-	Oct II-	May II-June I	Sept I-Sept II	Sept III- ³	May I-July I	
42 Pine, loblolly (<i>P. taeda</i>)*	Feb II- (Mar III-)	Oct II- (Sept I-Dec III ⁴)	Feb III-Mar I (Apr I-Apr II)	Oct (Sept III-Oct I)	Nov I-Dec III ² (Oct II-Dec III ²)		(Mar III-Aug II)

/1/ For conifers, dates of pollination are given. /2/ Seed fall continues through the winter, in smaller quantities. /3/ Seed fall continues for several years. /4/ Leaf fall continues throughout the year.

113. PHENOLOGICAL VALUES: FOREST TREES, U. S. A. (Concluded)

Within a species there is variation in time of growth expressions, depending upon such factors as latitude, altitude, slope, distribution of rainfall, and earliness or lateness of growing season. Many species have a broad distribution. Growth-period values are averages. Dates of stages where the growing season is short are enclosed in parentheses; dates of stages not so enclosed are for the long growing season. When the month is followed by I, growth stage occurs during first 10 days of the month; by II, during second 10 days; by III, during last 10 days. When no number appears after the month, growth stage occurs during the entire month. Species indicated by an asterisk (*) are evergreen; all other species are deciduous.

Species	Leafing	Leaf Falling	Flowering ¹	Seed Maturing	Seed Falling	Height Growth	Diameter Growth
Eastern United States (concluded)							
65 Pine, longleaf (<i>Pinus palustris</i>)*	Mar I-	Sept I-Dec III ⁴	Feb I-Mar III	Sept I-Oct II	Oct II-Nov III ⁺	Apr III-July I	Mar I-Aug III
66 Pine, pitch (<i>P. rigida</i>)*	May III-July III		Apr III-May II	To Oct III	Nov I-Apr III	May I-Aug I	Apr III-
67 Pine, red (<i>P. resinosa</i>)*	May III-Aug III	Oct I-	June I-June II	Sept II-Sept III	Oct I-Dec III ²		May I-Sept III
68 Pine, shortleaf (<i>P. echinata</i>)*	Feb III-	Sept I-Dec III ⁴	Feb III-				
69 (P. <i>echinata</i>)*	(May III-July III)		(May II)	(Oct I-Oct II)	(Oct III-Dec III ²)	(May I-July III)	(Mar III-Aug III)
70 Pine, slash (<i>P. elliotii</i>)*	Feb III-		June III-Feb II	Sept I-Sept II	Sept III-Nov I		
71 Redcedar (<i>Juniperus virginiana</i>)*	Mar II-May II	Oct	Mar II-May II	Sept III-Nov III	Feb I-Mar III		
72 Spruce, black (<i>Picea mariana</i>)*	June I-		June I	Aug III-Sept II	Sept III- ⁵	June I-Aug II	May III-Sept I
73 Spruce, red (<i>P. rubens</i>)*			June I	To Sept I	Sept II-	June I-July III	
74 Spruce, white (<i>P. glauca</i>)*	May II-May III		May	Aug III-Sept I	Sept II-Nov III	May II July III	
75 Sweetgum (<i>Liquidambar styraciflua</i>)	Mar II-Apr III		Mar II-May I	Sept II-Sept III	Oct		May III-Aug II
76 Sycamore, American (<i>Platanus occidentalis</i>)	Apr I-May I	Oct I-Nov I	Apr I-May I	Sept III	Oct I-Mar I ⁺	Apr I-July II	
77 Tamarack (<i>Larix laricina</i>)	May	Sept III-Oct III	Apr III-May III	Aug III-Sept I	Sept II-Sept III	May III-Aug II	May III-July I
78 Tupelo, black (<i>Myrica sylvatica</i>)	Apr		Apr II-May I	To Sept I	Sept II-Oct II		
79 (Myrica <i>sylvatica</i>)	(May)	(Sept III-Nov I)	(May III-June I)	(To Sept II)	(Sept III-Oct II)		
80 Walnut, black (<i>Juglans nigra</i>)	Apr	Sept III-Oct III	Apr I-May I	Sept	Oct I-Nov I		
81 (Juglans <i>nigra</i>)	(May II-May III)	(Oct I-Oct II)	(May)	(Sept)			
82 White-cedar, northern (<i>Thuja occidentalis</i>)*	May II-		May III	Aug III-Sept III	Oct	May II-Aug III	May III-Sept I
83 Willow, black (<i>Salix nigra</i>)	Mar III-Apr II	Oct II-Nov I	Mar II-Mar III	Apr I-Apr II	Apr III-May II		
84 (Salix <i>nigra</i>)	(Apr III-May II)	(Oct)	(Apr III-May I)	(May II-May III)	(June)		
85 Yellow-poplar (<i>Liriodendron tulipifera</i>)	Mar III-Apr II	Oct II-Nov I	Apr	Sept II-Sept III	Oct I-Jan I		
86 (Liriodendron <i>tulipifera</i>)	(Apr III-May II)	(Sept I-Oct III)	(May I-June I)			(Apr II-July III)	(May I-Aug I)
Western United States							
87 Alder, red (<i>Alnus rubra</i>)	Mar III-Apr II	To Nov I	Mar II-Apr I	Sept I	(Nov I-Dec III ²)		
88 (Alnus <i>rubra</i>)	(Apr II-May I)	(To Oct II)	(Apr III-May I)	(Oct II)			
89 Aspen, quaking (<i>Populus tremuloides</i>)	Apr III	Oct II-Nov II	Apr I-Apr II	May I	May II	Apr II-	
90 (Populus <i>tremuloides</i>)	(June I)	(Sept)	(June II)	(June III)	(July I)	(May III-Aug I)	(May III-Aug III)
91 Cottonwood, black (<i>P. trichocarpa</i>)	Apr	To Nov I	Apr II-Apr III	May III			
92 (P. <i>trichocarpa</i>)	(Apr III-May II)	(Sept III-Oct I)	(May II-May III)	(June III)			
93 Dogwood, Pacific (<i>Cornus nuttallii</i>)	Mar III-Apr II	To Nov I	Apr III-May II	Aug II			
94 (Cornus <i>nuttallii</i>)	(Apr III-May I)	(To Oct III)	(May I-June I)	(Sept I)			
95 Douglas fir (<i>Pseudotsuga menziesii</i>)*	May I-May II	Oct II-Nov I	Apr II-Apr III	Aug III-Sept II	Sept II-Oct II	May I-July III	May I-Aug II
96 (Pseudotsuga <i>menziesii</i>)*	(June III)	(Sept II-Sept III)	(July I)	(Aug II)	(Aug III-Sept II)	(June I-July III)	(May III-Aug I)
97 Fir, alpine (<i>Abies lasiocarpa</i>)*	June I	Aug II-Sept III	June I	Sept II	Sept III-Oct I	May III-July II	May III-Aug I
98 (Abies <i>lasiocarpa</i>)*	(June III)	(Sept I-Oct III)	(June III-July I)	(Aug III-Sept I)	(Sept II-Sept III)	(June II-July III)	
99 Fir, grand (<i>A. grandis</i>)*	May I-		May I		Sept II-Oct III		Apr III-Aug II
100 (A. <i>grandis</i>)*	(June I-)		(June II)	(Aug)	(Sept I-Oct III)		(May II-Sept II)
101 Fir, white (<i>A. concolor</i>)*	May II	Sept I-	June I			May I	
102 (A. <i>concolor</i>)*	(July I)	(Oct)	(May I-May II)		(Oct)	(June III-Aug I)	(May I-Aug I)
103 Hemlock, western (<i>Tsuga heterophylla</i>)*	May I-		May I	Aug II-Sept I	Sept II -		
104 (Tsuga <i>heterophylla</i>)*	(June I)	(Sept I-Dec III)	(May II)	(Sept II-Sept III)	(Oct I-Dec III ²)	(May III-Aug I)	(May II-Sept I)
105 Incense-cedar (<i>Libocedrus decurrens</i>)*	May III		May III		Oct I-Nov III	May III-Aug III	Apr II-Aug III
106 Juniper, Rocky Mt. (<i>Juniperus scopulorum</i>)*	May III		May III	Sept III	Oct I-	May I-	
107 (Juniperus <i>scopulorum</i>)*	(June I)		(June II)	(Oct I-Oct II)		(May III-)	
108 Larch, western (<i>Larix occidentalis</i>)	Apr II-		Apr III	Sept I	Oct I-		Apr III-July II
109 (Larix <i>occidentalis</i>)	(May II-)		(June I-June II)	(Aug I)	(Sept I-)		(May III-July II)
110 Maple, bigleaf (<i>Acer macrophyllum</i>)	Mar I-Apr I	Oct III-Nov III	Mar II-Apr I	To Sept III	Oct I-Dec III ²		May I-July III
111 (Acer <i>macrophyllum</i>)	(Apr II-May I)	(Sept III-Oct III)	(Apr III-May I)	(To Aug III)			
112 Oak, Calif. live (<i>Quercus agrifolia</i>)*	Mar I-Apr III		Apr		Dec I-Dec III ²		Mar III-July III
113 Oak, canyon live (<i>Q. chrysolepis</i>)*			June I		Oct	Apr II-July II	Apr III-Aug III
114 Oak, Gambel (<i>Q. gambelii</i>)	May III	Sept III-Oct I	May II-May III			May II	
115 (Q. <i>gambelii</i>)	(June I)	(Sept III)				(June I)	
116 Pine, Jeffrey (<i>Pinus jeffreyi</i>)*	June II-June III	Oct II-Nov I	June II-June III		Sept II-Oct II	May II-Aug I	Apr II-Sept II
117 Pine, limber (<i>P. flexilis</i>)*	May III-June II	Sept III-Oct III	June I	Sept	Oct	May III-July III	
118 (P. <i>flexilis</i>)*	(June I-June II)	(Oct)	(June III-July I)	(Aug III-Sept I)	(Sept II-Oct III)		
119 Pine, lodgepole (<i>P. contorta</i>)*	May	Oct I-Nov I	May II-May III	Sept I-Sept II	Sept III-Oct I ⁶	May I-July II	
120 (P. <i>contorta</i>)*	(June III)	(Sept II-Oct III)	(July I-July II)	(Aug)	(Sept I-)	(June III-)	
121 Pine, ponderosa (<i>P. ponderosa</i>)*	May III-June I	Oct I-Nov I	May III-June I	Aug I-Sept III	Sept I-Nov III	May I-Aug I	Apr II-Sept II
122 (P. <i>ponderosa</i>)*	(June II-July III)	(Sept I-Oct I)	(June II-June III)	(Aug)	(Sept)	(June I-July II)	(May III-Aug III)
123 Pine, sugar (<i>P. lambertiana</i>)*	July I-July II	Oct II-Nov II	June II-June III		Oct	May III-July II	Apr II-Aug III
124 Pine, western white (<i>P. monticola</i>)*	May II-		May III		Sept III-	May II-	May I-July II
125 (P. <i>monticola</i>)*	(June I-)		(June III-July I)	(Aug)	(Sept I-)		
126 Pinyon (<i>P. edulis</i>)*	May III-June I	Sept III-Oct III	May II-May III	Sept	Oct	May I-	
127 (P. <i>edulis</i>)*	(June II-Aug I)	(May III-June II)	(June II-June III)	(Aug I-Sept I)	(Sept III-Oct II)	(May III-July I)	(June I-Sept I)
128 Redcedar, western (<i>Thuja plicata</i>)*		Sept I-Oct III	Apr III	Sept III	Sept III-Dec III ²	May II-Sept I	Apr III-Oct I
129 (Thuja <i>plicata</i>)*			(May III)	(Aug II-Sept I)	(Sept I-)		(May II-Sept I)
130 Spruce, Engelmann (<i>P. engelmannii</i>)*	May III	Sept I-Sept II	May III-June I	Aug I-Sept I	Sept I-Oct I	May III-	May I-July II
131 (P. <i>engelmannii</i>)*	(June III)	(Sept I-Oct III)	(June III)	(Sept)	(Sept III-Oct II)	(June III-July III)	
132 Spruce, Sitka (<i>P. sitchensis</i>)*	Apr III-		May I		Sept III-		Apr III-Aug II
133 (P. <i>sitchensis</i>)*			(May III)	(Sept II-Sept III)	(Oct I-Dec III ²)	(May III-July II)	(May III-Sept I)

/1/ For conifers, dates of pollination are given. /2/ Seed fall continues through the winter, in smaller quantities. /4/ Leaf fall continues throughout the year. /5/ Cones are retained for 2-3 years during which seed fall continues. /6/ Most seeds are retained several years until cones are opened by a fire.

114. SIZE AND GROWTH RATE: FOREST TREES, U. S. A.

Values are approximate. Great variation exists within species.

Species	Height ¹ ft	Crown Spread ² ft	Trunk Diameter ³ ft	Relative Growth Rate	Species	Height ¹ ft	Crown Spread ² ft	Trunk Diameter ³ ft	Relative Growth Rate
1 Alaska-cedar (Chamaecyparis nootkatensis)	60-90(130)	15-20	2-3(7)	Slow	39 Elm, slippery (Ulmus rubra)	50-70(90)	40-60	1-2(4)	Rapid
2 Alder, red (Alnus rubra)	80-100(130)	20-40	1-3(5)	Rapid	40 Fir, alpine (Abies lasiocarpa)	60-100(160)	15-25	1.5-2(3)	Moderate
3 Ash, black (Fraxinus nigra)	40-60(90)	20-30	1-2(5)	Slow	41 Fir, balsam, (A. balsamea)	40-60(85)	20-25	1-1.5(3)	Rapid
4 Ash, blue (F. quadrangulata)	40-50(120)	30-40	1-2(4)	Rapid	42 Fir, California red (A. magnifica)	150-180(230)	20-40	4-5(10)	Moderate
5 Ash, green (F. pennsylvanica)	35-50(85)	30-40	1-2(2.5)	Rapid	43 Fir, Fraser (A. fraseri)	30-50(65)	20-25	1-2(2.5)	Moderate
6 Ash, Oregon (F. latifolia)	60-80(130)	30-40	2-3(5)	Moderate	44 Fir, grand (A. grandis)	120-160(250)	20-30	2-4(6)	Moderate
7 Ash, white (F. americana)	60-80(125)	50-70	2-3(6)	Rapid	45 Fir, noble (A. procera)	140-200(260)	20-40	2.5-5(8)	Rapid
8 Aspen, bigtooth (Populus grandidentata)	60-70(80)	20-30	1-2(3)	Rapid	46 Fir, Pacific silver (A. amabilis)	140-160(250)	20-40	2-4(6)	Moderate
9 Aspen, quaking (P. tremuloides)	40-60(120)	20-40	1-2(4.5)	Very rapid	47 Fir, white (A. concolor)	120-150(200)	20-30	3-4(6)	Moderate
10 Baldcypress (Taxodium distichum)	80-120(150)	20-30	2-5(12)	Slow	48 Hackberry (Celtis occidentalis)	40-80(130)	40-50	1-2(5)	Rapid
11 Basswood, American (Tilia americana)	60-80(125)	40-50	2-3(5)	Rapid	49 Hemlock, eastern (Tsuga canadensis)	60-80(160)	20-30	2-3(6)	Slow
12 Basswood, white (T. heterophylla)	60-80(125)	40-50	1.5-2.5(3)	Moderate	50 Hemlock, mountain (T. mertensiana)	70-100(130)	20-30	2.5-3.5(5)	Moderate
13 Beech, American (Fagus grandifolia)	70-100(120)	60-80	1-3(4)	Slow	51 Hemlock, western (T. heterophylla)	100-170(260)	15-25	2-5(9)	Moderate
14 Birch, gray (Betula populifolia)	20-30(60)	15-25	0.6-1(1.5)	Rapid	52 Hickory, bitternut (Carya cordiformis)	50-60(170)	20-30	1-2(4)	Moderate
15 Birch, paper (B. papyrifera)	50-70(120)	20-30	1-2(5)	Rapid	53 Hickory, mockernut (C. tomentosa)	50-70(100)	20-30	1-2.5(3.5)	Slow
16 Birch, river (B. nigra)	70-80(100)	40-50	2-3(5)	Rapid	54 Hickory, pignut (C. glabra)	50-60(85)	25-35	1-2(4)	Slow
17 Birch, sweet (B. lenta)	50-60(80)	20-30	1-2(5)	Moderate	55 Hickory, shagbark (C. ovata)	60-80(120)	20-30	1-2(4)	Slow
18 Birch, yellow (B. alleghaniensis)	60-80(100)	30-40	1-2(4)	Rapid	56 Hickory shellbark (C. laciniosa)	60-80(120)	20-30	1-2(4)	Slow
19 Boxelder (Acer negundo)	40-50(75)	30-40	1.5-3(6)	Very rapid	57 Holly, American (Ilex opaca)	40-50(100)	20-25	1-2(4)	Slow
20 Buckeye, Ohio (Aesculus glabra)	30-60(90)	30-40	1-2(2.5)	Moderate	58 Honeylocust (Gleditsia triacanthos)	70-80(140)	40-50	2-3(6)	Rapid
21 Buckeye, yellow (A. octandra)	70-90(100)	30-50	2-3(4)	Rapid	59 Hophornbeam, eastern (Ostrya virginiana)	30-40(55)	20-25	1-1.5(1.5)	Slow
22 Buckthorn (Rhamnus purshiana)	30-40(60)	15-25	0.5-1(3)	Rapid	60 Incense-cedar (Libocedrus decurrens)	80-110(190)	15-25	2.5-4(11)	Slow
23 Butternut (Juglans cinerea)	40-60(110)	20-30	1-2(3)	Rapid	61 Juniper, alligator (Juniperus deppeana)	30-50(60)	10-15	1.5-3(6)	Very slow
24 California-laurel (Umbellularia californica)	60-100(175)	30-50	1-3(6)	Moderate	62 Juniper, Rocky Mt. (J. scopulorum)	20-40(55)	10-15	1-2(3)	Slow
25 Catalpa, northern (Catalpa speciosa)	30-60(120)	40-50	1-3(5)	Rapid	63 Juniper, Utah (J. osteosperma)	15-20(30)	10-15	1-1.5(2.5)	Very slow
26 Cherry, black (Prunus serotina)	50-60(100)	20-40	1.5-3(5)	Rapid	64 Juniper, western (J. occidentalis)	20-30(40)	10-20	1-2.5(3)	Slow
27 Chestnut, American (Castanea dentata)	70-90(120)	50-70	2-4(10)	Rapid	65 Larch, western (Larix occidentalis)	140-180(210)	20-40	3-4(8)	Slow
28 Chinkapin, golden (Castanopsis chrysophylla)	60-80(150)	40-60	1-2.5(8)	Rapid	66 Locust, black (Robinia pseudoacacia)	40-60(100)	20-40	1-2(5)	Rapid
29 Cottonwood, black (Populus trichocarpa)	80-120(225)	30-50	3-4(8)	Rapid	67 Madrone, Pacific (Arbutus menziesii)	40-80(125)	20-40	1-2(4)	Slow
30 Cottonwood, eastern (P. deltoides)	80-100(175)	40-60	3-4(11)	Very rapid	68 Magnolia, southern (Magnolia grandiflora)	60-80(135)	30-35	2-3(4.5)	Moderate
31 Cottonwood, plains (P. sargentii)	50-80(110)	20-40	2-3(5)	Rapid	69 Mahogany, West Indies (Swietenia mahagoni) ⁴	30-40(60)	15-30	0.5-1(1.5)	Slow
32 Cucumbertree (Magnolia acuminata)	70-90(100)	50-60	2-3(5)	Rapid	70 Maple, bigleaf (Acer macrophyllum)	50-80(120)	30-60	1-3(8)	Rapid
33 Cypress, Arizona (Cupressus arizonica)	50-60(90)	15-25	1-2.5(5)	Slow	71 Maple, red (A. rubrum)	50-70(120)	40-60	1-2.5(5)	Rapid
34 Dogwood, flowering (Cornus florida)	20-40(50)	25-35	0.5-1(1.5)	Slow	72 Maple, silver (A. saccharinum)	60-80(120)	40-50	2-3(7)	Rapid
35 Dogwood, Pacific (C. nuttallii)	30-50(70)	20-30	0.5-1.5(2)	Slow	73 Maple, sugar (A. saccharum)	60-80(135)	40-50	2-3(5)	Slow
36 Douglas-fir (Pseudotsuga menziesii)	180-250(385)	15-40	4-6(15)	Rapid	74 Mulberry, red (Morus rubra)	20-40(50)	20-30	0.5-1(1.5)	Moderate
37 Elm, American (Ulmus americana)	80-100(120)	80-110	2-4(11)	Rapid	75 Oak, black (Quercus velutina)	50-80(130)	40-50	2-3(7)	Moderate
38 Elm, rock (U. thomasi)	50-70(100)	20-30	1-2.5(5)	Rapid	76 Oak, blackjack (Q. marilandica)	20-30(55)	20-30	0.5-1.5(2)	Slow

/1/ Average range at maturity. Values for maximum height are enclosed in parentheses. /2/ Maximum crown spread of open-grown trees. Data primarily adapted and modified from Robinson, F. B., "Useful Trees and Shrubs." These values are not usually measured by foresters and may be more variable than the other data. They are presented here to show a general growth habit. /3/ Average range at maturity. Values for maximum diameter are enclosed in parentheses. Measurements at breast height (4.5 ft). /4/ Attains greater size in tropics.

114. SIZE AND GROWTH RATE: FOREST TREES, U. S. A. (Concluded)

Values are approximate. Great variation exists within species.

Species	Height ¹ ft	Crown Spread ² ft	Trunk Diameter ³ ft	Relative Growth Rate	Species	Height ¹ ft	Crown Spread ² ft	Trunk Diameter ³ ft	Relative Growth Rate
77 Oak, blue (<i>Quercus douglasii</i>)	50-80(130)	20-40	1-2(3)	Slow	116 Pine, pitch (<i>Pinus rigida</i>)	50-60(100)	30-40	1-2(3)	Rapid
78 Oak, bur (<i>Q. macrocarpa</i>)	70-80(170)	40-50	2-3(7)	Slow	117 Pine, ponderosa (<i>P. ponderosa</i>)	100-180(235)	25-35	3-4(9)	Moderate
79 Oak, California black (<i>Q. kelloggii</i>)	50-80(100)	30-50	1.5-2.5(11)	Slow	118 Pine, red (<i>P. resinosa</i>)	50-80(120)	20-40	2-3(5)	Rapid
80 Oak, California live (<i>Q. agrifolia</i>)	30-60(110)	30-50	1-3(6)	Slow	119 Pine, shortleaf (<i>P. echinata</i>)	80-100(150)	25-35	2-2.5(4)	Rapid
81 Oak, California white (<i>Q. lobata</i>)	50-90(130)	40-60	305(10)	Rapid	120 Pine, slash (<i>P. elliotii</i>)	80-90(130)	30-40	1-2(3)	Rapid
82 Oak, canyon live (<i>Q. chrysolepis</i>)	60-80(100)	50-120	2-4(11)	Slow	121 Pine, spruce (<i>P. glabra</i>)	80-90(120)	20-30	2-2.5(4)	Rapid
83 Oak, chestnut (<i>Q. prinus</i>)	50-60(100)	30-40	2-3(6)	Moderate	122 Pine, sugar (<i>P. lambertiana</i>)	160-180(250)	20-40	2-4(10)	Rapid
84 Oak, chinkapin (<i>Q. muehlenbergii</i>)	60-80(160)	30-40	2-3(4)	Rapid	123 Pine, Virginia (<i>P. virginiana</i>)	30-40(100)	15-25	1-1.5(3)	Moderate
85 Oak, emory (<i>Q. emoryi</i>)	30-50(65)	20-40	1-2(3)	Slow	124 Pine, western white (<i>P. monticola</i>)	150-180(210)	25-35	2.5-3.5(8)	Rapid
86 Oak, Gambel (<i>Q. gambelii</i>)	20-30(50)	20-30	0.5-1(1.5)	Slow	125 Pinyon (<i>P. edulis</i>)	15-30(50)	10-25	1-2(3)	Very slow
87 Oak, laurel (<i>Q. laurifolia</i>)	60-70(100)	20-40	2-3(7)	Moderate	126 Pinyon, singleleaf (<i>P. monophylla</i>)	20-30(50)	10-25	1-2(3)	Very slow
88 Oak, live (<i>Q. virginiana</i>)	40-50(100)	40-75	3-4(11)	Moderate	127 Poplar, balsam (<i>Populus balsamifera</i>)	60-80(100)	40-60	1-2(5)	Rapid
89 Oak, northern red (<i>Q. rubra</i>)	60-70(150)	30-50	2-3(11)	Rapid	128 Port-Orford-cedar (<i>Chamaecyparis lawsoniana</i>)	140-180(225)	20-40	3.5-6(16)	Moderate
90 Oak, Nuttall (<i>Q. nuttallii</i>)	50-70(120)	20-40	1-2(3.5)	Moderate	129 Redcedar, eastern (<i>Juniperus virginiana</i>)	40-50(100)	10-15	1-2(4)	Slow
91 Oak, Oregon, white (<i>Q. garryana</i>)	50-70(120)	50-80	2-3(8)	Slow	130 Redcedar, western (<i>Thuja plicata</i>)	150-200(250)	20-30	4-8(20)	Rapid
92 Oak, overcup (<i>Q. lyrata</i>)	40-70(110)	30-40	1.5-2.5(4.5)	Slow	131 Redwood (<i>Sequoia sempervirens</i>)	150-275(365)	30-40	6-12(20)	Rapid
93 Oak, pin (<i>Q. palustris</i>)	60-80(120)	40-50	2-3(5)	Rapid	132 Sassafras (<i>Sassafras albidum</i>)	40-70(110)	35-45	1-2.5(6)	Rapid
94 Oak, post (<i>Q. stellata</i>)	40-50(100)	25-35	1-2(4)	Slow	133 Sequoia, giant (<i>Sequoia gigantea</i>)	250-280(350)	30-60	10-15(38)	Rapid
95 Oak, scarlet (<i>Q. coccinea</i>)	70-80(110)	40-50	2-3(4)	Moderate	134 Spruce, black (<i>Picea mariana</i>)	30-40(100)	20-30	0.5-1(3)	Slow
96 Oak, Shumard (<i>Q. shumardii</i>)	80-100(180)	40-60	4-5(8)	Rapid	135 Spruce, blue (<i>P. pungens</i>)	70-100(150)	15-25	1-2(3)	Slow
97 Oak, southern red (<i>Q. falcata</i>)	60-80(110)	40-50	2-3(7)	Moderate	136 Spruce, Engelmann (<i>P. engelmannii</i>)	100-120(165)	15-25	1-3(6)	Slow
98 Oak, swamp chestnut (<i>Q. michauxii</i>)	60-80(120)	30-40	2-3(9)	Slow	137 Spruce, red (<i>P. rubens</i>)	60-70(120)	20-25	1-2(4)	Slow
99 Oak, swamp white (<i>Q. bicolor</i>)	60-70(100)	40-50	2-3(7)	Slow	138 Spruce, Sitka (<i>P. sitchensis</i>)	180-200(300)	25-35	2-5(16)	Rapid
100 Oak, water (<i>Q. nigra</i>)	60-70(125)	40-60	1.5-3(5)	Rapid	139 Spruce, white (<i>P. glauca</i>)	60-70(120)	15-20	1.5-2(4)	Slow
101 Oak, white (<i>Q. alba</i>)	80-100(150)	60-90	2.5-4(8)	Slow	140 Sugarberry (<i>Celtis laevigata</i>)	60-80(130)	30-40	1.5-2.5(5)	Moderate
102 Oak, willow (<i>Q. phellos</i>)	80-100(130)	30-50	1.5-3(6)	Moderate	141 Sweetgum (<i>Liquidambar styraciflua</i>)	80-140(200)	60-70	2-5(6)	Rapid
103 Osage-orange (<i>Maclura pomifera</i>)	20-50(70)	30-40	1-2(5)	Moderate	142 Sycamore (<i>Platanus occidentalis</i>)	80-120(175)	60-80	2-5(14)	Rapid
104 Palmetto, cabbage (<i>Sabal palmetto</i>)	30-50(90)	10-20	1-1.5(2)	Slow	143 Tamarack (<i>Larix laricina</i>)	40-80(100)	20-30	1-2(3)	Moderate
105 Pecan (<i>Carya illinoensis</i>)	90-120(180)	30-50	2-4(6)	Moderate	144 Tanoak (<i>Lithocarpus densiflora</i>)	70-90(150)	30-50	1-3(7)	Moderate
106 Persimmon (<i>Diospyros virginiana</i>)	30-50(130)	20-30	1-1.5(7)	Slow	145 Tupelo, black (<i>Nyssa sylvatica</i>)	50-80(100)	20-30	2-3(4)	Rapid
107 Pine, Digger (<i>Pinus sabiniana</i>)	40-50(90)	15-25	1-2(4)	Moderate	146 Tupelo, water (<i>N. aquatica</i>)	80-100(120)	20-30	3-4(5)	Rapid
108 Pine, eastern white (<i>P. strobus</i>)	80-120(220)	40-50	2-4(6)	Rapid	147 Walnut, black (<i>Juglans nigra</i>)	50-90(150)	60-80	2-3(7)	Rapid
109 Pine, jack (<i>P. banksiana</i>)	30-60(90)	10-20	1-1.5(2)	Rapid	148 White-cedar, Atlantic (<i>Chamaecyparis thyoides</i>)	50-80(120)	10-20	1-2.5(5)	Slow
110 Pine, Jeffery (<i>P. jefferyi</i>)	90-100(130)	25-35	3-4(9)	Moderate	149 White-cedar, northern (<i>Thuja occidentalis</i>)	30-50(125)	5-10	2-3(6)	Slow
111 Pine, knobcone (<i>P. attenuata</i>)	60-80(100)	25-35	1-2(3)	Rapid	150 Willow, black (<i>Salix nigra</i>)	30-40(120)	20-30	1-2(6)	Rapid
112 Pine, limber (<i>P. flexilis</i>)	30-50(85)	15-25	1.5-2.5(7)	Slow	151 Willow, peachleaf (<i>S. amygdaloides</i>)	20-40(60)	15-25	1-1.5(3)	Rapid
113 Pine, loblolly (<i>P. taeda</i>)	90-110(190)	30-40	2-2.5(5)	Rapid	152 Yellow-poplar (<i>Liriodendron tulipifera</i>)	80-120(200)	30-40	2-5(12)	Rapid
114 Pine, lodgepole (<i>P. contorta</i>)	30-70(150)	15-25	1-2.5(3)	Slow	153 Yew, Pacific (<i>Taxus brevifolia</i>)	20-40(65)	15-25	1-1.5(2)	Slow
115 Pine, longleaf (<i>P. palustris</i>)	80-120(150)	20-30	2-3(4)	Rapid					

/1/ Average range at maturity. Values for maximum height are enclosed in parentheses. /2/ Maximum crown spread of open-grown trees. Data primarily adapted and modified from Robinson, F. B., "Useful Trees and Shrubs." These values are not usually measured by foresters and may be more variable than the other data. They are presented here to show a general growth habit. /3/ Average range at maturity. Values for maximum diameter are enclosed in parentheses. Measurements at breast height (4.5 ft).

115. SIZE AND GROWTH RATE: TREES, SHRUBS

Data adapted from Robinson, F.B., "Useful Trees and Shrubs." Values are approximate because variations in soil, moisture, air circulation, and light conditions have marked effect on growth; data should be used with caution.

Species	Height ¹ ft	Spread ² ft	Relative Growth Rate	Species	Height ¹ ft	Spread ² ft	Relative Growth Rate
1 Ailanthus (Ailanthus altissima)	50-60	35-45	Rapid	83 Katsura tree (Cercidiphyllum japonicum)	20-40	30-40	Moderate
2 Alder (Alnus glutinosa)	35-50	25-30	Moderate	84 Larch (Larix decidua)	70-90	20-30	Rapid
3 Alder (A. incana)	10-15	10-15	Rapid	85 Lead plant (Amorpha canescens)	2-4	3-4	Moderate
4 Alder (A. rugosa)	15-25	15-20	Moderate	86 Leucothoe (Leucothoe catesbaei)	5-8	4-8	Slow
5 Aralia (Acanthopanax sieboldianus)	5-10	4-8	Moderate	87 Magnolia (Magnolia soulangeana)	20-25	20-30	Moderate
6 Arborvitae (Thuja koraiensis)	8-15	3-5	Slow	88 Magnolia (M. stellata)	15-25	15-20	Slow
7 Arborvitae (T. orientalis)	20-35	10-15	Rapid	89 Magnolia (M. tripetala)	20-25	25-30	Moderate
8 Ash (Fraxinus excelsior)	80-100	65-90	Rapid	90 Magnolia (M. virginiana)	20-30	10-15	Moderate
9 Barberry (Berberis thunbergii)	3-6	4-5	Slow	91 Maple (Acer ginnala)	12-20	8-12	Rapid
10 Basswood (Tilia cordata)	70-90	40-50	Slow	92 Maple (A. japonicum)	20-25	15-20	Slow
11 Beautyberry (Callicarpa japonica)	3-5	3-5	Moderate	93 Maple (A. palmatum)	15-20	15-20	Slow
12 Beautybush (Kolkwitzia amabilis)	5-10	8-10	Moderate	94 Maple (A. platanoides)	50-60	60-70	Rapid
13 Beech (Fagus sylvatica)	80-100	50-70	Slow	95 Maple (A. pseudoplatanus)	60-70	50-60	Rapid
14 Blackhaw (Viburnum prunifolium)	10-15	8-10	Moderate	96 Maple (A. spicatum)	25-30	20-25	Moderate
15 Birch (Betula alba)	40-50	20-30	Rapid	97 Mountain-ash (Sorbus americana)	25-30	20-25	Rapid
16 Birch (B. nana)	3-5	3-5	Slow	98 Mountain-ash (S. aucuparia)	20-40	15-30	Moderate
17 Birch (B. pumila)	3-8	2-5	Slow	99 Mountain-laurel (Kalmia latifolia)	8-15	8-10	Slow
18 Buckeye (Aesculus parviflora)	5-10	8-12	Moderate	100 Mulberry (Morus alba)	20-30	30-40	Rapid
19 Buckthorn (Rhamnus cathartica)	8-12	10-12	Moderate	101 Ninebark (Physocarpus opulifolius)	10-12	10-12	Rapid
20 Buckthorn (R. frangula)	8-15	6-8	Moderate	102 Oak (Quercus robur)	60-90	60-80	Slow
21 Buttonbush (Cephalanthus occidentalis)	5-15	5-10	Moderate	103 Oregon grape (Mahonia aquifolium)	3-8	3-5	Moderate
22 Catalpa (Catalpa bignonioides)	30-50	20-40	Rapid	104 Papaw (Asimina triloba)	15-30	15-25	Slow
23 Catalpa (C. ovata)	15-25	12-18	Rapid	105 Paulownia (Paulownia tomentosa)	40-50	30-40	Moderate
24 Cedar (Cedrus atlantica)	90-120	80-100	Moderate	106 Peashrub (Caragana arborescens)	10-20	8-18	Rapid
25 Cedar (C. deodara)	140-170	100-120	Rapid	107 Photinia (Photinia villosa)	8-20	5-15	Moderate
26 Cedar (C. libani)	75-120	80-100	Slow	108 Pine (Pinus bungeana)	70-90	45-55	Slow
27 Cedrela (Cedrela sinensis)	40-50	30-40	Rapid	109 Pine (P. cembra)	25-40	15-30	Very slow
28 Chaste-tree (Vitex agnus-castus)	15-20	8-12	Moderate	110 Pine (P. nigra)	60-100	30-40	Rapid
29 Cherry (Prunus avium)	35-50	20-30	Rapid	111 Pine (P. sylvestris)	70-90	40-50	Rapid
30 Cherry (P. cerasus)	20-30	15-20	Rapid	112 Poplar (Populus alba)	80-100	40-70	Very rapid
31 Chinquapin (Castanea pumila)	8-30	10-30	Rapid	113 Poplar (P. nigra)	50-60	60-70	Very rapid
32 Cherry-laurel (Prunus caroliniana)	20-40	15-20	Rapid	114 Poplar (P. nigra italica)	35-50	5-10	Very rapid
33 Chokeberry (Aronia arbutifolia)	6-10	4-6	Moderate	115 Privet (Ligustrum amurense)	10-15	10-12	Rapid
34 Chokeberry (A. melanocarpa)	4-6	2-3	Moderate	116 Privet (L. ovalifolium)	15-25	10-15	Rapid
35 Chokecherry (Prunus virginiana)	15-25	10-20	Rapid	117 Privet (L. quihoui)	5-8	6-8	Moderate
36 Clethra (Clethra alnifolia)	5-10	4-8	Moderate	118 Privet (L. vulgare)	15-20	15-20	Rapid
37 Coralberry (Symphoricarpos vulgaris)	3-6	4-8	Rapid	119 Quince (Cydonia oblonga)	4-8	6-10	Moderate
38 Cork tree (Phellodendron amurense)	40-50	30-40	Moderate	120 Redbud (Cercis canadensis)	25-40	25-35	Slow
39 Cork tree (P. sachalinense)	30-50	20-30	Rapid	121 Rhododendron (Rhododendron carolinianum)	4-6	4-5	Moderate
40 Crab apple (Malus arnoldiana)	15-20	15-20	Rapid	122 Rhododendron (R. catawbiense)	8-10	8-10	Moderate
41 Crab apple (M. baccata)	25-35	15-20	Rapid	123 Rhododendron (R. maximum)	10-15	10-15	Slow
42 Crab apple (M. coronaria)	20-25	20-25	Moderate	124 Rhododendron (R. nudiflora)	5-10	3-6	Slow
43 Crab apple (M. sargentii)	8-10	10-12	Moderate	125 Rhododendron (R. vaseyi)	8-15	4-10	Moderate
44 Cryptomeria (Cryptomeria japonica)	70-100	30-35	Slow	126 Rhododendron (R. viscosa)	3-8	3-8	Moderate
45 Cypress (Cupressus macrocarpa)	45-65	30-40	Moderate	127 Russian-olive (Elaeagnus angustifolia)	15-25	30-35	Moderate
46 Cypress (C. sempervirens)	70-90	8-12	Slow	128 Saltbush (Baccharis halimifolia)	4-10	8-10	Rapid
47 Devil's-walkingstick (Aralia spinosa)	20-30	10-15	Rapid	129 Scholartree (Sophora japonica)	30-60	30-50	Rapid
48 Dogwood (Cornus alba)	5-10	5-12	Slow	130 Serviceberry (Amelanchier arborea)	20-40	10-15	Rapid
49 Dogwood (C. alternifolia)	15-25	20-40	Moderate	131 Serviceberry (A. laevis)	20-30	15-20	Rapid
50 Dogwood (C. mas)	10-20	8-12	Moderate	132 Serviceberry (A. rotundifolia)	10-20	10-20	Rapid
51 Dogwood (C. sanguinea)	10-15	10-15	Moderate	133 Sheeplaurel (Kalmia angustifolia)	2-4	2-5	Slow
52 Dogwood (C. stolonifera)	8-12	8-10	Slow	134 Silk tree (Albizia julibrissen)	25-35	30-40	Rapid
53 Elder (Sambucus canadensis)	5-15	5-12	Rapid	135 Smoke tree (Cotinus coggygria)	15-20	15-20	Slow
54 Elder (S. nigra)	10-15	10-15	Rapid	136 Snowberry (Symphoricarpos racemosus)	4-6	4-6	Rapid
55 Elder (S. racemosa)	6-12	6-12	Rapid	137 Spicebush (Benzoin aestivale)	8-12	4-8	Slow
56 Elm (Ulmus campestris)	90-120	50-60	Rapid	138 Spruce (Picea abies)	80-120	20-30	Rapid
57 Elm (U. glabra)	80-100	50-65	Rapid	139 Spruce (P. omorika)	70-90	20-25	Slow
58 Elm (U. pumila)	30-60	20-40	Very rapid	140 Spruce (P. orientalis)	70-100	20-30	Slow
59 Filbert (Corylus americana)	3-8	5-10	Rapid	141 Sumac (Rhus aromatic)	6-10	6-10	Moderate
60 Filbert (C. avellana)	15-25	15-20	Rapid	142 Sumac (R. copallina)	10-30	20-25	Rapid
61 Fir (Abies homolepis)	40-50	20-25	Moderate	143 Sumac (R. glabra)	10-15	10-15	Rapid
62 Fir (A. nordmanniana)	90-120	20-30	Moderate	144 Sumac (R. typhina)	10-20	5-15	Rapid
63 Fir (A. veitchii)	70-80	25-35	Moderate	145 Sweetshrub (Calycanthus floridus)	5-8	6-10	Moderate
64 Fringetree (Chionanthus virginicus)	10-30	8-25	Slow	146 Sycamore (Platanus orientalis)	60-70	50-60	Rapid
65 Ginkgo (Ginkgo biloba)	50-80	30-40	Slow	147 Viburnum (Viburnum rhytidophyllum)	5-12	8-12	Rapid
66 Goldenchaintree (Laburnum anagyroides)	20-25	15-20	Slow	148 Viburnum (V. tomentosum)	8-10	8-10	Moderate
67 Goldenraintree (Koeleruteria paniculata)	25-35	30-40	Slow	149 Wax myrtle (Myrica pensylvanica)	6-12	2-8	Slow
68 Hawthorn (Crataegus crus-galli)	25-35	20-30	Slow	150 Wayfaring-tree (Viburnum lantana)	12-15	6-12	Moderate
69 Hawthorn (C. oxyacantha)	15-20	10-20	Moderate	151 White-cedar (Chamaecyparis obtusa)	70-80	20-30	Slow
70 Hawthorn (C. pedicellata)	10-20	10-20	Slow	152 White-cedar (C. pisifera)	100-120	10-20	Moderate
71 Hawthorn (C. phaenopyrum)	15-25	20-25	Moderate	153 Willow (Salix alba vitellina)	40-70	30-40	Very rapid
72 Hemlock (Tsuga caroliniana)	35-45	20-25	Moderate	154 Willow (S. babylonica)	30-40	30-40	Very rapid
73 Holly (Ilex aquifolium)	30-40	20-25	Slow	155 Willow (S. Caprea)	15-20	10-15	Very rapid
74 Holly (I. crenata)	5-12	8-12	Slow	156 Winterberry (Ilex verticillata)	5-10	3-5	Slow
75 Honeysuckle (Lonicera morrowi)	6-8	6-10	Rapid	157 Witch-hazel (Hamamelis japonica)	20-25	15-20	Slow
76 Honeysuckle (L. tatarica)	10-12	10-12	Very rapid	158 Witch-hazel (H. virginiana)	15-25	15-20	Slow
77 Horsechestnut (Aesculus hippocastanum)	40-65	30-40	Moderate	159 Yaupon (Ilex vomitoria)	10-15	5-8	Slow
78 Horsechestnut (A. pavia)	10-15	8-15	Rapid	160 Yellowroot (Zanthorhiza apiifolia)	2-4	3-5	Moderate
79 Indigobush (Amorpha fruticosa)	5-10	6-12	Rapid	161 Yellowwood (Cladrastis lutea)	35-45	35-40	Moderate
80 Inkberry (Ilex glabra)	8-12	10-12	Slow	162 Yew (Taxus baccata)	20-30	15-25	Very slow
81 Juniper (Juniperus chinensis)	15-20	2-4	Moderate				
82 Juniper (J. sabina)	4-10	5-8	Slow				

1/ Average height at maturity. 2/ Spread of crown when grown in open habitat.

116. MAXIMUM GROWTH RATE: PLANTS AND PLANT ORGANS

Species	Material and Dimension	Growth Rate ¹	Time and Specification ²	Maximum Size	Time and Specification ²	Environmental Conditions	
						Location	Special Factor
1 Nitella sp	Internodal cell, length	A: 1.7 mm/da R-E: 1.1/da ³	0-1 da after 0.4 mm long	13 mm	10 da after 0.4 mm long	Laboratory	Mineral nutrient, 23-26°C, fluorescent light.
3 Phycomyces blakesleeenans	Sporangiphore, length	A: 3.0 mm/hr R: 1/8 hr	Stage 4 ⁴ Stage 4 ⁴ , 0.8 mm fr tip			Laboratory	Moist chamber, 22-25°C.
4 Daedalea quercina	Mycelial pellets, oven-dry weight	A: 45 mg/da	0-8 da	482 mg	14 da	Laboratory	70-ml shake culture, optimal synthetic medium, 28°C, inoculum 0.03 mg.
6 Fromes geotropus		A: 193 mg/da	0-7 da	1350 mg	7 da		
7 F. subroseus		A: 30 mg/da	1-8 da	298 mg	14 da		
8 Lentinus tingrinus		A: 140 mg/da	1-7 da	924 mg	7 da		
9 L. trabea		A: 93 mg/da	0-7 da	652 mg	7 da		
10 Polyporus palustris		A: 60 mg/da	0-6 da	402 mg	14 da		
11 P. tulipiferus		A: 75 mg/da	1-6 da	552 mg	14 da		
12 Trametes serialis		A: 112 mg/da	0-7 da	789 mg	7 da		
13 Bamboo (Dendrocalamus sp)	Stem, length	A: 26.7 cm/da	1-2 mo after bud opening	14 m	2.5 mo after bud opening	Field	Daily fluctuating temp 23-32°C, daily rain.
14 Bamboo (Sinocalamus oldhami)	Stem, length	A: 31.4 cm/da ⁵ Sample average: night, 0.97 cm/hr; day, 0.71 cm/hr	18 da after buds appeared above ground, height of 7 shoots of 1 plant, 3.2-7.7 m	Not reached at end of observations		Field	Sept 27-Oct 15, 1953; Cuba.
15 Barley (Hordeum sativum)	Kernel, length	A: 1.8 mm/da R: 0.35/da	3 da after pollination	9 mm	20 da after pollination	Field	Mean temp 26°C.
16 Kernel, length		A: 4.8 mg/da R: 0.5/da	2 da after pollination	9 mm	20 da after pollination		
17 Kernel, fresh weight		A: 2.2 mg/da R: 0.58/da	6 da after pollination	57 mg	24 da after pollination		
18 Kernel, fresh weight			2 da after pollination	57 mg	24 da after pollination		
19 Kernel, dry weight			12 da after pollination	32 mg	24 da after pollination		
20 Kernel, dry weight			2 da after pollination	32 mg	24 da after pollination		
21 Corn (Zea mays)	Plant, dry weight	A: 19.8 g/wk R: 1.37/wk	13 wk after planting	122 g	16 wk after planting	Field	
22 Primary root, length		A: 2.0 mm/hr E: 0.4/hr	2 da after soaking seed			Laboratory	On moist filter paper, 25°C, in darkness.
23 Flower bud, length		A: 11.5 mm/da R: 0.077/da	2 da before anthesis	155 mm	At anthesis	Greenhouse	Daily fluctuating temp between means, 16-27°C.
24 Flower bud, length		A: 0.077/da R: 0.088/da	2-30 da before anthesis	155 mm	At anthesis		
25 Anther, length		A: 0.18/da R: 0.18/da	20-30 da before anthesis	29 mm	At anthesis		
26 Anther, fresh weight		A: 0.18/da R: 0.18/da	20-30 da before anthesis	160 mm	At anthesis		
27 Anther, dry weight			20-30 da before anthesis	35 mg	9 da before anthesis		
28 Tobacco (Nicotiana glauca)	Leaf, area	E: 0.85/da ⁶	Leaf 8.6 cm long, 3 cm from base, 0.5 cm from midrib				
29 Tomato (Lycopersicon esculentum)	Stem, length	A: 29.3 mm/da	6 wk after planting			Laboratory	Daily alternation of 8 hr light, 26.5°C, and 16 hr dark, 17°C.

/1/ The growth curve of a plant or organ is frequently sigmoid in form with (1) an acceleration phase, (2) a short, or sometimes prolonged, linear phase, and (3) a final phase of deceleration. Absolute rates (A) pertain to phase 2 and are maximum rates. They are estimates of the instantaneous rate dX/dt , where X is the dimension measured and t is time. Relative rates (R) are estimated maximum values of $(1/X)(dX/dt)$, where X is the dimension measured and t is time. Relative elemental rate (E) pertains to an infinitesimal portion, or element, of length (dX), area (dA), et al., of the organ under consideration. The maximum relative elemental rate of growth of an organ therefore is the relative rate of growth of that infinitesimal portion which is growing most rapidly. For increase in a linear dimension, the relative elemental rate has the form $d(dX/dt)/dX$, and for increase in area $d(dA/dt)/dA + d(dY/dt)/dY$. /2/ Time growth rate and/or maximum size attained. For relative elemental rates (E), location within organ is specified. /3/ Growth is uniform over length of internodal cell; hence relative rate of elongation of cell as a whole equals relative elemental rate for each point. /4/ Stage of growth following formation of the sporangium. /5/ Average rate: 24.9 cm/da. /6/ Assuming that drawings of leaf (Avery, G.S., 1933) were made at weekly intervals.

117. GROWTH RATES: PLANT TISSUE CULTURES

Tissue	Growth Period da	Initial Weight mg	Relative Increase W_1/W_0 ¹	Relative Growth Rate (100 r) ¹	Culture Medium ²	Tissue	Growth Period da	Initial Weight mg	Relative Increase W_1/W_0 ¹	Relative Growth Rate (100 r) ¹	Culture Medium ²
Artichoke (Helianthus tuberosus)						Endive (Chicorium intybus)					
1 Tuber	60	100	2.0	1.1	G	26 Tuber	60	100	3.7	2.2	G
2 Tuber	60	100	5.4	2.8	G+0.3 mg/L IAA	27 Tuber	60	100	5.9	3.0	G+0.3 mg/L IAA
3 Crown gall	60	100	5.1	2.7	G	Marigold (Tagetes erecta)					
4 Crown gall	60	100	4.5	2.5	G+0.3 mg/L IAA	28 Tumor	42	35	25	7.6	H
5 Tuber	35	283	1.1	0.2	G	29 Tumor	42	35	29	8.0	H+0.5% dulcitol
6 Tuber	35	247	1.9	1.8	G+0.3 mg/L IAA	30 Tumor	42	35	31	8.1	H+0.5% methanol
7 Tuber	35	245	3.0	3.2	G+25% coconut milk	Periwinkle (Vinca rosea)					
8 Tuber	35	237	4.4	4.2	G+100% coconut milk	31 Tumor	42	35	12.7	6.1	H
Carrot (Daucus carota)						Potato (Solanum tuberosum)					
9 Root cambium	67	170	20.3	4.5	G+0.1 mg/L IAA	32 Tuber	35	3	55	11.1	W+6% coconut milk ³
10 Root cambium	0-7	170	2.0	9.9		Rutabaga (Brassica campestris)					
11 Root cambium	7-15	340	1.6	6.0		33 Root	60	100	4.1	2.4	G
12 Root cambium	15-21	548	1.7	9.0		34 Root	60	100	5.6	2.9	G+0.3 mg/L IAA
13 Root cambium	21-41	941	2.0	3.3		Salsify (Scorzonera hispanica)					
14 Root cambium	41-67	1852	2.1	2.7		35 Root	60	100	6.4	3.1	G
15 Root cambium	24	4.0	59	17		36 Root	60	100	9.4	3.7	G+1.0 mg/L IAA
16 Root cambium	0-2	4.0	1.2	7.0		37 Crown gall	42	100	8.8	3.6	G
17 Root cambium	2-4	4.6	1.2	9.1		38 Crown gall	35	100	9.2	3.7	G+1.0 mg/L IAA
18 Root cambium	4-6	5.6	1.6	22.9		Snake palm (Amorphophallus rivieri)					
19 Root cambium	6-8	8.8	1.7	27		39 Tuber	42	250	6	4.3	G+15% coconut milk
20 Root cambium	8-10	15.1	2.0	34	W+15% coconut milk	Sunflower (Helianthus annuus)					
21 Root cambium	10-12	30	1.9	32		40 Crown gall	42	25	5.2	3.9	W ₁
22 Root cambium	12-14	57	1.6	22.4		41 Crown gall	42	25	13.6	6.2	W ₂
23 Root cambium	14-16	92	1.6	22.4		Tobacco (Nicotiana, hybrid) ⁴					
24 Root cambium	16-20	139	1.4	8.6		42 Stem	42	25	4.8	3.8	W ₁
25 Root cambium	20-24	197	1.2	4.3		43 Stem	42	25	7.8	4.9	W ₃

/1/ $W_1/W_0 = e^{rt}$, where W_0 is initial weight, W_1 is final weight, e is the base of natural log, r is the instantaneous growth rate expressed as per cent increase per day, and t is growth period in days. /2/ Abbreviations: G=Gautheret's agar; H=Hildebrandt et al.; W=White's liquid medium; W₁=White's agar; W₂=modified White's agar for sunflower tissue; W₃=modified White's agar for tobacco tissue; IAA = indoleacetic acid. /3/ Plus 2,4-dichlorophenoxyacetic acid, 18 mg/L. /4/ N. glauca x N. langsdorffii.

118. ROOT SYSTEMS

Part I: NUMBER, SIZE

Species	Roots: Number ¹				Roots: Total Length, cm ^{1,2}				Root Hairs: Diameter, μ ¹			Root Hairs: Length, μ ¹		
	I	II	III	IV	I	II	III	IV	I	II	III	I	II	III
1 Equisetaceae: Equisetum (Equisetum arvense)									15	15		1200	1200	
2 Equisetum (E. kansanum)									13	13		1500	1500	
3 Pinaceae: Douglas-fir (Pseudotsuga menziesii) ^{3,4}	1	6.3	5.0	0.3	10.1	11.5	1.9	0.03	21.8	22.9	22.0	240	125	155
4 Juniper (Juniperus monosperma) ^{3,5}	1	3.4	2.0		4.8	6.4	0.8		14.9	15.3	14.0	70	84	56
5 Pine (Pinus ponderosa) ^{3,6}	1	15	70	12	100	505	465	23	24	26	22	140	155	240
6 Spruce (Picea engelmanni) ^{3,7}	1	12	43	4.7	75	140		0.5	18	18	18	140	125	110
7 Typhaceae: Cattail (Typha latifolia)		25 ⁸								12			1200	
8 Gramineae: Bentgrass (Agrostis astoriana)									13	12	12	600	600	50
9 Bentgrass (A. tenuis)									10	10	10	400	400	300
10 Bermudagrass (Cynodon dactylon)	4	660	22		60	1980	9		12	8	8	770	270	260
11 Bluegrass (Poa pratensis) ⁹	900	39700	43900		5490	26520	6100		11	9	7	1120	935	510
12 Fescue (Festuca commutata)									13	13	12	400	400	350
13 Foxtail grass (Setaria viridis)	12	3360			170	405			8	8		100	100	
14 Love grass (Eragrostis curvula)									8	8	8	270	270	200
15 Oat (Avena sativa) ¹⁰	110	2190	2400		915	2440	1220		14	13	13	1400	1100	860
16 Rye (Secale cereale) ¹¹	130	3670	2600		1220	3960	1220		15	12	12	1720	940	590
17 Wheat (Triticum aestivum) ¹²					2000	1230								
18 Wheatgrass (Agropyron elongatum)									12	12	12	800	750	750
19 Wheatgrass (A. palustris)									11	11	10	900	800	800
20 Amarantaceae: Amaranth (Amaranthus torreyi)	1	40	325	255	8	730	280	25		9	9	230	220	
21 Leguminosae: Clover (Trifolium repens)	35	980	135		245	685	27		8	8	7	250	250	200
22 Honeylocust (Gleditsia triacanthos)										13	13	200	180	
23 Kudzu vine (Pueraria hirsuta)	1	54	755		9	380	225		12	12	11	150	140	140
24 Parosela (Parosela daleda)	1	52	1560	1560	13	520	1560	310	15	15	150	110	110	90
25 Soybean (Glycine soja)	1	51	470	260	11	255	375	105	17	17	14	240	80	80
26 Ulmaceae: Elm (Ulmus pumila)	1	55	1100	88000	55	2200	8800	176000		10			200	
27 Hackberry (Celtis occidentalis)									8	8		170	170	
28 Chenopodiaceae: Russian thistle (Salsola pestifer)	1	105	3150	630	35	1050	630	63		8	7	160	140	
29 Caryophyllaceae: Grasswort (Cerastium arvense)	1	14	105		7	35	16		12	12	10	750	600	600
30 Cruciferae: Descurainia (Descurainia pinnata)	1	10	520	1560	5	130	1040	470	7	7	6	350	300	210
31 Capparidaceae: Cleome (Cleome serrulata)										6			150	
32 Zygophyllaceae: Tribulus (Tribulus terrestris)	1	200	160		25	160	32		7	7		140	130	
33 Euphorbiaceae: Euphorbia (Euphorbia albomarginata)	1	22	220		11	220	155		9	8	8	300	240	240
34 Umbelliferae: Sium (Sium suave)									8	8		150	150	
35 Oleaceae: Ash (Fraxinus lanceolata)									5	5		370	370	
36 Convolvulaceae: Bindweed (Convolvulus arvensis)	1	28	170		14	335	32		14	14		80	80	
37 Labiateae: Catnip (Nepeta cataria)	1	100	1200	200	10	300	600	20	8	8	8	410	390	340
38 Solanaceae: Nightshade (Solanum eleagnifolium)	1	130	650		65	650	325			7	7	120	110	
39 Bignoniaceae: Catalpa (Catalpa bignonioides)										10	10	250	250	
40 Plantaginaceae: Plantain (Plantago major)	26	635	1450		275	1150	435		12	10	10	220	210	200
41 Compositae: Dandelion (Taraxacum officinale)	1	180	900		30	720	360		7	7		130	130	
42 Marigold (Tagetes patula)	1	72	430		12	110	130		14	14	14	180	160	140

/1/ I = main roots, i.e., roots arising directly from base of plant, may be seminal or adventitious; II = secondary roots, i.e., roots arising directly from main roots; III = tertiary roots, i.e., roots arising directly from secondary roots; IV = quaternary roots, i.e., roots arising directly from tertiary roots. /2/ Total length of roots in the specified categories refers to their combined lengths. /3/ Data applicable to seedlings, 6 months old. /4/ Total surface area of roots, 300 sq mm; total surface area of root hairs, 54 sq mm. /5/ Total surface area of roots, 1830 sq mm; total surface area of root hairs, 27 sq mm. /6/ Total surface area of roots, 1350 sq mm; total surface area of root hairs, 180 sq mm. /7/ Total surface area of roots, 260 sq mm; total surface area of root hairs, 110 sq mm. /8/ Per cm of main roots. /9/ Total surface area of roots, 2140 sq cm; total volume, 13900 cu mm; total surface area of root hairs, 15780 sq cm; number of root hairs in a core of soil 3 inches in diameter and 6 inches deep, 51.5 million. /10/ Surface area of roots, 320 sq cm; total volume, 2610 cu mm; surface area of root hairs, 3440 sq cm; number of root hairs in a core of soil (cf Fn 9), 6.3 million. /11/ Surface area of roots, 505 sq cm; total volume, 4580 cu mm; surface area of root hairs, 7680 sq cm; number of root hairs in a core of soil (cf Fn 9), 12.5 million. /12/ Surface area of roots, 310 sq cm.

Part II: EXTENT

Species	Location and Soil Type	Age	Condition of Growth	Extent of Roots			
				Depth		Spread	
				cm	ft	cm	ft
1 Alfalfa (Medicago sativa)	Nebr.; alluvial silt loam.	2 yr		366	12	<30	<1
2 Apple (Pyrus malus)	N.Y.; heavy clay.	25 yr		>152	>5	>396	>13
3 Apple (P. malus)	Nebr.; porous loess.	3 yr			14-16		7-10
4		17 yr			30-35		≥15
5 Apricot (Prunus armeniaca) ¹	Okl.; silt loam over clay.			244	8	975	32
6 Asparagus (Asparagus officinalis)	Nebr.; silt loam over clay.	6 yr		305	10	122	4
7 Bean, kidney (Phaseolus vulgaris)	Nebr.; silt loam over clay.	2.5 mo	Mature pods.	137	4.5	61	2
8 Beet, garden (Beta vulgaris)	Nebr.; silt loam over clay.	3.5 mo	Edible roots.	305	10	122	4
9 Cabbage (Brassica oleracea capitata)	Nebr.; silt loam over clay.	4 mo	Mature heads.	238	7.8	107	3.5
10 Corn (Zea mays)	Nebr.; silt loam underlain by loess.	4 mo	Mature.	250	8.2	122	4
11 Lettuce (Lactuca sativa)	Nebr.; silt loam over clay.	3 mo	Flowering.	183	6	46	1.5
12 Oak, bur (Quercus macrocarpa)	Nebr.; silt loam.	65 yr ²		>305	>10	1829	60
13 Oat (Avena sativa)	Nebr.; silt loam underlain by loess.	3 mo	Grain maturing.	207	6.8	40	1.3
14 Peach (Prunus persica)	Ga.; sandy top soil, clay subsoil.	2 yr		91	3	183	6
15 Pecan (Carya illinoensis)	Ga.; sandy top soil, clay subsoil.	6 yr		183	6	732	24
16 Pine, pitch (Pinus rigida)	N.Y.; sandy soil	30 yr		274	>9	975	32 ³
17 Potato (Solanum tuberosum)	Nebr.; silt loam underlain by loess.	3 mo	Mature tubers.	143	4.7	64	2.1
18 Squash (Cucurbita maxima)	Nebr.; silt loam over clay.	2.6 mo	Fruiting.	183	6	579	19
19 Tomato (Lycopersicon esculentum)	Nebr.; silt loam over clay.	4 mo	Fruiting.	137	4.5	168	5.5
20 Wheat (Triticum aestivum)	Nebr.; silt loam underlain by loess.	3 mo	Mature grain.	204	6.7	40	1.3

/1/ Seedling. /2/ Height of tree, 37.5 ft. /3/ Range, 30-35 ft.

119. INTERCELLULAR SPACE: LEAVES

Between the upper and lower epidermis of a leaf are numerous intercellular spaces or air chambers constituting a connected system throughout the leaf. Values are volume of intercellular space expressed as per cent of total volume of leaf and, unless otherwise specified, are applicable to mature leaves of plants grown out-of-doors in full sunlight. Values for leaves in shade are enclosed in parentheses.

Species	Volume, %	Method ¹	Species	Volume, %	Method ¹
1 Alfalfa (<i>Medicago sativa</i>), early spring leaf	29	C	79 Grapefruit (<i>Citrus grandis</i>)	23	C
2 Alfalfa (<i>M. sativa</i>), late spring leaf	27	C	80 Greenbrier (<i>Smilax mauritanica</i>)	23	W
3 Alfalfa (<i>M. sativa</i>), secondary leaf	26	C	81 Guevina (<i>Guevina avellana</i>), dried leaf ²	45	W
4 Alfalfa (<i>M. sativa</i>), tertiary leaf	23	C	82 Guevina (<i>G. avellana</i>), in greenhouse ³	50	W
5 Alfalfa (<i>M. sativa</i>), quaternary leaf	19	C	83 Hepatica (<i>Hepatica angulosa</i>)	25	T
6 Amaryllis (<i>Amaryllis curvifolia</i>)	36	W	84 Honeysuckle (<i>Lonicera tartarica</i>)	10	T
7 Anthropolium (<i>Anthropolium paniculatum</i>)	14	W	85 Hopseedbush (<i>Dodonaea viscosa</i>), in greenhouse	14	W
8 Anthurium (<i>Anthurium digitatum</i>)	12	W	86 Horsechestnut (<i>Aesculus rubicunda</i>), mature leaf	26(23)	T
9 Apple, delicious (<i>Pyrus malus</i>)	35	C	87 Horsechestnut (<i>A. rubicunda</i>), immature leaf	6(6)	T
10 Apple, liveland (<i>P. malus</i>)	34	C	88 Horsechestnut (<i>A. rubicunda</i>), inner leaf	(38)	T
11 Arctocalyx (<i>Arctocalyx endlicherianus</i>)	8.4	W	89 Horsechestnut (<i>A. rubicunda</i>), peripheral leaf	(33)	T
12 Ardisia (<i>Ardisia crenulata</i>)	22	W	90 Ivy, English (<i>Hedera helix</i>)	30;24	W;T
13 Aristolochia (<i>Aristolochia labiosa</i>)	30	W	91 Jewelweed (<i>Impatiens</i> sp.), in dry habitat	34	T
14 Arum (<i>Arum maculatum</i>)	57	W	92 Jewelweed (<i>I. sp.</i>), in moist habitat	49	T
15 Ash (<i>Fraxinus excelsior</i>), inner leaf	(28)	T	93 Katsura tree (<i>Cercidiphyllum japonicum</i>), mature leaf	18(26)	T
16 Ash (<i>F. excelsior</i>), peripheral leaf	19(21)	T	94 Katsura tree (<i>C. japonicum</i>), immature leaf	6(6)	T
17 Aster (<i>Aster scaber</i>)	(41)	W	95 Laurelcherry (<i>Prunus laurocerasus</i>)	29	W
18 Aucuba (<i>Aucuba japonica</i>)	27	W	96 Leopardbane (<i>Doronicum</i> sp.), dried leaf ²	22	W
19 Banana (<i>Musa paradisica sapientum</i>)	25-48	W	97 Leopardbane (<i>Doronicum</i> sp.), in greenhouse ³	59	W
20 Barberry (<i>Berberis nervosa</i>)	(36)	C	98 Leopardbane (<i>Doronicum</i> sp.), in field	71	W
21 Basswood (<i>Tilia cordata</i>), mature leaf	20(26)	T	99 Life-plant (<i>Bryophyllum calycinum</i>), in greenhouse	17	C
22 Basswood (<i>T. cordata</i>), immature leaf	3.5(4)	T	100 Ligularia (<i>Ligularia tibetica</i>)	54	W
23 Bean (<i>Phaseolus</i> sp.), dry habitat	19	T	101 Ligularia (<i>L. tussilaginea</i>)	(43)	W
24 Bean (<i>Phaseolus</i> sp.), moist habitat	27	T	102 Lilac (<i>Syringa vulgaris</i>), mature leaf	20(28) ⁴	T
25 Beech (<i>Fagus sylvatica</i>), mature leaf	22(28)	T	103 Lilac (<i>S. vulgaris</i>), immature leaf	9(10)	T
26 Beech (<i>F. sylvatica</i>), immature leaf	5(6)	T	104 Lily (<i>Lilium candidum</i>)	20	T
27 Beech (<i>F. sylvatica</i>), inner leaf	(32)	T	105 Loosetrife (<i>Lysimachia ciliata</i>), dried leaf ²	24	W
28 Beech (<i>F. sylvatica</i>), peripheral leaf	(29)	T	106 Loosetrife (<i>L. ciliata</i>), in greenhouse ³	31	W
29 Begonia (<i>Begonia hydrocotylifolia</i>)	3.5	W	107 Loosetrife (<i>L. ciliata</i>), in field	59	W
30 Begonia (<i>B. incarnata</i>)	19	W	108 Loosetrife (<i>L. clethroides</i>)	(33)	W
31 Bergenia (<i>Bergenia cordifolia</i>), dried leaf ²	26	W	109 Mahonia (<i>Mahonia aquifolium</i>)	18	W
32 Bergenia (<i>B. cordifolia</i>), greenhouse ³	26	W	110 Maple (<i>Acer pseudoplatanus</i>)	25	T
33 Bloodlily (<i>Haemanthus coccineus</i>)	21	W	111 Marlea (<i>Marlea plantanifolia</i>)	(25)	W
34 Bocconia (<i>Bocconia frutescens</i>)	27	W	112 Nasturtium (<i>Tropaeolum</i> sp.), dry habitat	17	T
35 Bougainvillea (<i>Bougainvillea glabra</i>) ³	19	T	113 Nasturtium (<i>Tropaeolum</i> sp.), moist habitat	35	T
36 Boxwood (<i>Buxus sempervirens</i>)	19	T	114 New Zealand spinach (<i>Tetragonia expansa</i>)	22;18	W;C
37 Cacalia (<i>Cacalia definifolia</i>)	(35)	W	115 Oak (<i>Quercus coccinea</i>), mature leaf	24(33)	T
38 Camellia (<i>Camellia japonica</i>)	22;29	W;C	116 Oak (<i>Q. coccinea</i>), immature leaf	8(8)	T
39 Camphortree (<i>Camphora officinalis</i>)	7.7	W	117 Oleander (<i>Nerium oleander</i>), top leaf ⁵	30	C
40 Canna (<i>Canna tubiflora</i>)	15	W	118 Oleander (<i>N. oleander</i>), bottom leaf ⁶	34	C
41 Cassine (<i>Cassine maurocenia</i>), dried leaf ²	17	W	119 Oleander (<i>N. oleander</i>), top leaf ⁵	27	C
42 Cassine (<i>C. maurocenia</i>), greenhouse ³	17	W	120 Oleander (<i>N. oleander</i>) bottom leaf ⁶	42	C
43 Catalpa (<i>Catalpa speciosa</i>), large leaf	32	C	121 Orange (<i>Citrus sinensis</i>) ³	29	W
44 Catalpa (<i>C. speciosa</i>), medium leaf	43	C	122 Paspalum (<i>Paspalum setaceum</i>)	6.8	W
45 Catalpa (<i>C. speciosa</i>), small leaf	(31)	C	123 Pear (<i>Pyrus communis</i>)	13(22)	T
46 Cestrum (<i>Cestrum laurifolium</i>)	40	W	124 Pentstemon (<i>Pentstemon barbatus</i>)	20	T
47 Chirita (<i>Chirita sinensis</i>)	14	W	125 Periwinkle (<i>Vinca minor</i>)	23	W
48 Chrysanthemum (<i>Chrysanthemum morifolium</i>) ²⁸	20	W	126 Petteria (<i>Petteria ramentacea</i>)	20	T
49 Coprosma (<i>Coprosma baueri</i>) ³	20	W	127 Photinia (<i>Photinia glabra</i>), old leaf	22(26)	W
50 Corn (<i>Zea mays</i>)	28	C	128 Photinia (<i>P. glabra</i>), young leaf	24(27)	W
51 Dahlia (<i>Dahlia variabilis</i>)	23	W	129 Pistia (<i>Pistia texensis</i>)	71	W
52 Dipteracanthus (<i>Dipteracanthus schauerianus</i>)	29	W	130 Plantain-lily (<i>Hosta japonica</i>)	28	W
53 Drimys (<i>Drimys</i> sp.), dried leaf ²	19	W	131 Plectranthus (<i>Plectranthus fruticosus</i>)	18	W
54 Drimys (<i>Drimys</i> sp.), in greenhouse ³	25	W	132 Psidium (<i>Psidium cuneatum</i>)	16	W
55 Dogwood (<i>Cornus sanguinea</i>), mature leaf	21(29)	T	133 Redbud (<i>Cercis canadensis</i>)	32	C
56 Dogwood (<i>C. sanguinea</i>), immature leaf	9(12)	T	134 Rhododendron (<i>Rhododendron oreodoxum</i>)	23	T
57 Elder (<i>Sambucus nigra</i>)	20	T	135 Sagittaria (<i>Sagittaria trifolia</i>)	36;39	W;C
58 Elder (<i>S. sieboldiana</i>)	(24)	W	136 Sarcococca (<i>Sarcococca pruniformis</i>)	17	W
59 English-daisy (<i>Bellis perennis</i>)	23	T	137 Saxifraga (<i>Saxifraga stolonifera</i>)	39	W
60 Epimedium (<i>Epimedium pubigerum</i>)	19	T	138 Sedum (<i>Sedum sieboldii</i>)	(28)	W
61 Eucalyptus (<i>Eucalyptus globulus</i>)	30	C	139 Sedum, stone crop (<i>S. viride</i>)	(43)	W
62 Euonymus (<i>Euonymus americanus</i>)	24	T	140 Senecio (<i>Senecio doria</i>)	58	W
63 Euonymus (<i>E. japonicus</i>)	23	W	141 Senecio (<i>S. nemorensis</i>)	64	W
64 Ficus (<i>Ficus oppositifolia</i>)	20	W	142 Solanum (<i>Solanum serpentinum</i>)	25	W
65 Filbert (<i>Corylus tubulosa</i>), mature leaf	17(33)	T	143 Sorrel (<i>Rumex acetosa</i>)	27(30)	W
66 Filbert (<i>C. tubulosa</i>), immature leaf	7(11)	T	144 Sowthistle (<i>Sonchus oleraceus</i>)	27	W
67 Flowering-maple (<i>Abutilon theophrasti</i>)	33	C	145 Sycamore (<i>Platanus occidentalis</i>), inner leaf	(27)	T
68 Garlic (<i>Allium ursinum</i>), dried leaf ²	20	W	146 Sycamore (<i>P. occidentalis</i>), peripheral leaf	(33)	T
69 Garlic (<i>A. ursinum</i>), in greenhouse ³	52	W	147 Tobacco (<i>Nicotiana tabacum</i>)	26	W
70 Garlic (<i>A. ursinum</i>), in field	66	W	148 Tovar (<i>Tovar filiformis</i>)	28(34) ⁷	W
71 Gentian (<i>Gentiana tibetica</i>)	41	W	149 Turnip (<i>Brassica rapa</i>)	18	W
72 Ginkgo (<i>Ginkgo biloba</i>)	41	C	150 Valerian (<i>Valeriana officinalis</i>)	(30)	W
73 Globedaisy (<i>Globularia incanescens</i>)	25	T	151 Violet (<i>Viola mandschurica</i>)	23(20)	W
74 Glorybird (<i>Calystegia soldanella</i>)	37	W	152 Violet (<i>V. rossii</i>)	27	W
75 Goldenrod (<i>Solidago sempervirens</i>)	53	W	153 Walnut (<i>Juglans regia</i>), inner leaf	(25)	T
76 Granadilla (<i>Passiflora quadrangularis</i>)	21	W	154 Walnut (<i>J. regia</i>), peripheral leaf	18(21)	T
77 Grape, European (<i>Vitis vinifera</i>)	13	T	155 Waterchestnut (<i>Trapa natans</i>)	20	W
78 Grape, riverbank (<i>V. vulpina</i>)	25	C	156 Wax-plant (<i>Hoya carnosa</i>)	14	W

/1/ Methods of determination: W = measurement made by infiltrating intercellular space with water; C = measurement made on camera lucida drawings of leaf sections; T = measurement by infiltrating intercellular space with turpentine. /2/ Leaf dried 30 min prior to measurement. /3/ In greenhouse, plants growing in well-watered and well-lighted conditions. /4/ Measurements made on camera lucida drawings: in sun, 21%; in shade, 24%. /5/ Plants under artificial light of 175 ft.-candles. /6/ Plant under artificial light of 77 ft.-candles. /7/ Measurements made on camera lucida drawings: in sun, 33%; in shade, 39%.

120. DISTRIBUTION AND SIZE OF STOMATA: LEAVES

Stomata are pores through which occur gaseous diffusion. Values for upper leaf surface are followed by those for lower surface. Number of stomata are per sq cm of leaf surface.

Species	No. /sq cm	Pore Size μ^1	Species	No. /sq cm	Pore Size μ^1
1 Abronia (<i>Abronia villosa</i>) ²	20,000;20,000		36 Mulberry (<i>Morus alba</i>)	0;48,000	
2 Acacia (<i>Acacia aneura</i>)	11,200;11,200		37 Nasturtium (<i>Tropaeolum majus</i>)	0;13,000	; 12x6
3 Ailanthus (<i>Ailanthus altissima</i>)	0;38,600		38 Nightshade (<i>Solanum dulcamara</i>)	6,000;26,300	
4 Alfalfa (<i>Medicago sativa</i>)	16,900;13,800		39 Oat (<i>Avena sativa</i>)	2,500;2,300	31x7;38x8
5 Apple, delicious (<i>Pyrus malus</i>)	0;29,400		40 Oak, English (<i>Quercus robur</i>)	0;45,000 ⁵	
6 Apple, Grimes golden (<i>P. malus</i>)	0;41,200		41 Oak, scarlet (<i>Q. coccinea</i>)	0;103,800	
7 Avena (<i>Geum parviflora</i>)	7,500;23,000		42 Oak, Spanish (<i>Q. triloba</i>)	0;119,200	;5x1
8 Barberry (<i>Berberis vulgaris</i>)	0;40,000		43 Parafoxia (<i>Parafoxia linearis</i>) ²	22,000;23,600	
9 Barley (<i>Hordeum vulgare</i>)	5,500;5,400		44 Pea, garden (<i>Pisum sativum</i>)	10,100;21,600	
10 Basswood (<i>Tilia vulgaris</i>)	0;13,000		45 Peach (<i>Prunus persica</i>)	0;22,500	
11 Bean (<i>Phaseolus vulgaris</i>)	4,000;28,100	8x3;7x3	46 Plantain (<i>Alisma plantago-aquatica</i>)	5,000;3,600	
12 Begonia (<i>Begonia coccinea</i>)	0;4,000	;21x8	47 Plantain (<i>Plantago triandra</i>)	15,500;20,000	
13 Brachycome (<i>Brachycome sinclairii</i>)	22,000;15,000		48 Poplar, black (<i>Populus nigra</i>)	2,000;11,500	
14 Cabbage (<i>Brassica oleracea</i> cap.)	14,100;22,600		49 Potato (<i>Solanum tuberosum</i>)	5,100;16,100	
15 Castor bean (<i>Ricinus communis</i>)	6,400;17,600	8x4;10x4	50 Primrose (<i>Oenothera deltoidea</i>) ²	17,300;17,300	
16 Cherry (<i>Prunus cerasus</i>)	0;24,900		51 Rye (<i>Secale cereale</i>)	5,100;46,000	
17 Coleus (<i>Coleus blumei</i>)	0;14,100	;10x5	52 Salt-bush (<i>Atriplex vesicarium</i>)	12,000;12,000	
18 Corn (<i>Zea mays</i>)	5,200;6,800	19x4;19x5	53 Scilla (<i>Scilla nutans</i>) dry atmos.	5,500;4,950 ⁶	
19 Coach-whip (<i>Fouquieria splendens</i>) ²	7,100;7,100		54 Scilla (<i>S. nutans</i>), moist atmos.	2,750;2,400 ⁷	
20 Cucumber (<i>Cucumis sativus</i>)	22,100;44,200		55 Sorrel, wood (<i>Oxalis acetosella</i>)	0;5,600	
21 Elder (<i>Sambucus nigra</i>), in sun	0;4,000-26,000		56 Soybean (<i>Glycine soja</i>)	14,700;16,600	
22 Elder (<i>S. nigra</i>), in shade	0;1,200-14,000		57 Spearwort (<i>Ranunculus lingua</i>)	1,300;2,700	
23 Ficara (<i>Ficara verna</i>), in sun	1,850;4,250 ³		58 Speedwell (<i>Veronica fruticulosa</i>)	22,400;18,600	
24 Ficara (<i>F. verna</i>), in shade	2,700;4,900 ⁴		59 Stitchwort (<i>Malachium aquatica</i>)	3,100;5,400	
25 Forget-me-not (<i>Myosotis scorpioides</i>)	700;9,100		60 Sunflower (<i>Helianthus annuus</i>)	8,500;15,600	18x8;22x8
26 Frogbit (<i>Hydrocharis morsus-ranae</i>)	8,900;0		61 Sun-rose (<i>Helianthemum alpestre</i>)	28,600;20,400	
27 Geranium (<i>Pelargonium domesticum</i>)	1,900;5,900	23x8;24x9	62 Sycamore (<i>Platanus occidentalis</i>)	0;27,800	
28 Globedaisy (<i>Globularia nudicaulis</i>)	8,800;35,700		63 Tomato (<i>Lycopersicon esculentum</i>)	1,200;13,000	10x5;13x6
29 Groundsel (<i>Senecio cottonii</i>)	0;51,200		64 Walnut, black (<i>Juglans nigra</i>)	0;46,100	
30 Holly, American (<i>Ilex opaca</i>)	0;17,000	;12x6	65 Wandering-jew (<i>Zebrina pendula</i>)	0;1,400	;31x12
31 Ivy, English (<i>Hedera helix</i>)	0;15,800	;11x4	66 Water-soldier (<i>Stratiotes aloides</i>)	3,800;4,900	
32 Jimson weed (<i>Datura stramonium</i>)	11,400;18,900		67 Water lily (<i>Nymphaea alba</i>)	46,000;0	
33 Lilac (<i>Syringa vulgaris</i>)	0;33,000		68 Water lily (<i>N. thermalis</i>)	62,500;0	
34 Lychnis (<i>Lychnis alpina</i>)	15,600;14,600		69 Wheat (<i>Triticum aestivum</i>)	3,300;1,400	40x7;38x7
35 Marsh marigold (<i>Caltha palustris</i>)	0;4,000		70 Yew, English (<i>Taxus baccata</i>)	0;11,500	

/1/ Pore fully open. /2/ In desert. /3/ Average of 900-2800 (upper); 2800-5700 (lower). /4/ Average of 1000-4400 (upper); 2800-7000 (lower). /5/ Additional species not listed in table: black oak (*Q. velutina*), 58,000; northern red oak (*Q. rubra*), 68,000; willow oak (*Q. phellos*), 72,000. (Upper surface for all, O.) /6/ Average of 1100-9900 (upper); 900-9000 (lower). /7/ Average of 1100-4400 (upper); 1300-3500 (lower).

121. RATIO OF INTERNAL TO EXTERNAL SURFACE: LEAVES

Between the upper and lower epidermis of a leaf are layers of mesophyll cells surrounded by intercellular spaces. The internal surface (I), of the leaf consisting of all the mesophyll surfaces in contact with intercellular spaces, is much larger than the external surface (E), formed by the two epidermal layers. The ratio presented is that of total internal surface to total external (both upper and lower surfaces). Values are applicable to leaves of plants grown in full sunlight; those for leaves in shade are enclosed in parentheses.

Species	Surface Ratio I:E	Species	Surface Ratio I:E
1 Alfalfa (<i>Medicago sativa</i>), early spring leaf	15	16 Coleus (<i>Coleus blumei</i>)	4.6
2 Alfalfa (<i>M. sativa</i>), late spring leaf	14	17 Eucalyptus (<i>Eucalyptus globulus</i>)	31
3 Alfalfa (<i>M. sativa</i>), secondary leaf	11	18 Flowering-maple (<i>Abutilon theophrasti</i>)	11
4 Alfalfa (<i>M. sativa</i>), tertiary leaf	10	19 Gaultheria (<i>Gaultheria shallon</i>)	(8.2)
5 Alfalfa (<i>M. sativa</i>), quaternary leaf	9.9	20 Grape, riverbank (<i>Vitis vulpina</i>)	12
6 Apple, delicious (<i>Pyrus malus</i>) ¹	24	21 Grapefruit (<i>Citrus grandis</i>)	17
7 Apple, liveland (<i>P. malus</i>) ¹	23	22 Holly, American (<i>Ilex opaca</i>)	(13)
8 Apple, Jonathan (<i>P. malus</i>) ²	14	23 Lemon (<i>Citrus limonia</i>)	22
9 Apple, wealthy (<i>P. malus</i>) ²	15	24 Life-plant (<i>Bryophyllum calycinum</i>)	7.9
10 Apple, York (<i>P. malus</i>) ²	12	25 Lilac (<i>Syringa vulgaris</i>)	13(6.8)
11 Barberry (<i>Berberis nervosa</i>)	(9.9)	26 Oleander (<i>Nerium oleander</i>)	20
12 Castor bean (<i>Ricinus communis</i>)	(13)	27 Redbud (<i>Cercis canadensis</i>)	16
13 Catalpa (<i>Catalpa speciosa</i>), leaf large	19	28 Sumac (<i>Rhus glabra</i>)	16
14 Catalpa (<i>C. speciosa</i>), leaf medium	14	29 Tobacco (<i>Nicotiana tabacum</i>)	7.1
15 Catalpa (<i>C. speciosa</i>), leaf small	(9.3)		

/1/ Twenty-year-old tree. /2/ Two-year-old tree.

122. SURFACE AREA AND NUMBER: LEAVES

Values for needle leaves, indicated by an asterisk (*), represent the entire surface; values for flat leaves must be multiplied by 2 to obtain the entire externally exposed leaf surface (both upper and lower).

Part I: SURFACE AREA PER LEAF

Species	Leaf Surface sq cm/leaf ¹	Species	Leaf Surface sq cm/leaf ¹
1 Alfalfa (Medicago sativa), early spring leaf	2	43 Lemon (Citrus limonia)	37-40
2 Alfalfa (M. sativa), late spring leaf	2	44 Lime (C. aurantifolia)	13-14.5
3 Alfalfa (M. sativa), secondary leaf	1.2	45 Kumquat (Fortunella margarita)	9
4 Alfalfa (M. sativa), tertiary leaf	0.6	46 Maple (Acer saccharum)	73
5 Alfalfa (M. sativa), quaternary leaf	0.4	47 Milkweed (Asclepias arenaria)	48
6 Apple, laxton (Pyrus malus)	18	48 Musa (Musa acuminata)	0.7-2 sq m
7 Atalantia (Atalantia citroides)	9	49 Morning glory (Ipomoea purpurea), 1st leaf	35
8 Atalantia (A. disticha)	3	50 Morning glory (I. purpurea), 3rd leaf	50
9 Balsamocitrus (Balsamocitrus gabonensis)	12	51 Morning glory (I. purpurea), 5th leaf	80
10 Banana (Musa paradisiaca sapientum)	2700-5200	52 Morning glory (I. purpurea), 7th leaf	100
11 Basswood (Tilia americana)	73	53 Oleander (Nerium oleander), 300 ft-c	10.5
12 Bean (Phaseolus vulgaris), 15 da old	49	54 Oleander (N. oleander), 86 ft-c	11
13 Beech (Fagus sp)	22 ²	55 Orange (Citrus sinensis), 3 yr old	3-130
14 Box-orange (Severinia buxifolia)	3.5	56 Orange (C. sinensis), 29 yr old	2-48
15 Catalpa (Catalpa speciosa), small leaf	29-71	57 Pepperweed (Lepidium alyssoides)	5
16 Catalpa (C. speciosa), medium leaf	135	58 Periwinkle (Vinca rosea), 300 ft-c	4.5
17 Catalpa (C. speciosa), large leaf	240-380	59 Periwinkle (V. rosea), 86 ft-c	4
18 Cherry-orange (Citropsis schweinfurthii)	10	60 Pine (Pinus banksiana), 36 yr old	
19 Citron (Citrus medica)	20-33	61 Unthinned forest	52.4 sq mm*
20 Clappia (Clappia suadifolia)	0.7	62 Heavily thinned	51.6 sq mm*
21 Coldenia (Coldenia hispiddissima)	0.2	63 Moderately thinned	49.7 sq mm*
22 Corn (Zea mays)	600-1320	64 Pine (P. contorta), dry habitat	128 sq mm*
23 Cottonwood (Populus fremontii wislizenii)	50	65 Pine (P. contorta), moist habitat	232 sq mm*
24 Crownbeard (Verbesina encelioides)	12	66 Pine (P. resinosa), 27 yr old	401 sq mm*
25 Cucumber (Cucumis sativus), cotyledons	15	67 Pine (P. strobus), 27 yr old	122 sq mm*
26 Cucumber (C. sativus), 1st leaf	18	68 Pummelo (Citrus grandis)	40
27 Cucumber (C. sativus), 2nd leaf	29	69 Ragweed (Ambrosia trifida)	100
28 Cucumber (C. sativus), 3rd leaf	33	70 Redbud (Cercis canadensis)	65
29 Date (Phoenix dactylifera), 12 yr old	43,700	71 Saltbush (Atriplex canescens)	1
30 Desert-lime (Eremocitrus glauca)	60 sq mm	72 Seepweed (Suaeda suffrutescens)	59 sq mm
31 Elm (Ulmus americana)	54	73 Spruce (Picea engelmannii), dry habitat	44 sq mm*
32 Fingerlime (Microcitrus australasica)	40 sq mm	74 Spruce (P. engelmannii), moist habitat	69 sq mm*
33 Fir (Abies lasiocarpa), moist habitat	80 sq mm*	75 Sumac (Rhus trilobata)	21
34 Fir (A. lasiocarpa), dry habitat	55 sq mm*	76 Sunflower (Helianthus annuus)	38
35 Frankenia (Frankenia jamesii)	0.2	77 Tabog (Chaetospermum glutinosum)	8.6
36 Gooseberry (Ribes rotundifolium)	2-16.5	78 Taro (Colocasia antiquorum)	9100
37 Gourd (Cucurbita foetidissima)	560	79 Trifoliolate-orange (Poncirus trifoliata)	5
38 Grape, malaga (Vitis vinifera)	125-150	80 Wheat (Triticum aestivum), 1st leaf ³	5
39 Grape, muscat (V. vinifera)	88	81 Wheat (T. aestivum), 3rd leaf ³	13
40 Grapefruit (Citrus paradisi)	40-45	82 Wheat (T. aestivum), 5th leaf ³	15
41 Greggia (Greggia camporum)	2	83 Yellow-poplar (Liriodendron tulipifera)	130
42 Groundsel (Senecio spartioides)	5	84 Zinnia (Zinnia grandiflora)	0.8

/1/ Values are sq cm unless otherwise specified. /2/ Calculated. /3/ Plants under artificial light, 600 ft-c.

Part II: NUMBER OF LEAVES AND TOTAL LEAF SURFACE AREA PER PLANT

Species	Leaves		Species	Leaves	
	no./plant	sq cm/plant		no./plant	sq cm/plant
1 Alfalfa (Medicago sativa)	88 ¹	16,000	32 Orange (Citrus sinensis), 29 yr old	172,613	2,000,000
2 Apple (Pyrus malus), 2 yr old		11,000	33 Peach (Prunus persica), 5 yr old ³		922,000
3 Apple (P. malus), 5 yr old		294,000	34 Peach (P. persica), 5 yr old ⁴		750,000
4 Apple (P. malus), 9 yr old	20,000	318,000	35 Pepperweed (Lepidium alyssoides)	1318 ²	6700
5 Barley (Hordeum vulgare), 49 da old		900	36 Periwinkle (Vinca rosea), 86 ft-c	163	630
6 Bean (Phaseolus vulgaris), 15 da old	2	98	37 Periwinkle (V. rosea), 300 ft-c	257	1150
7 Beech (Fagus sp), in forest	35,000	780,500 ²	38 Pine (Pinus banksiana), 36 yr old		
8 Beech (Fagus sp), in open field	200,000	4,460,000 ²	39 Unthinned forest	744,924	390,000* ⁵
9 Beet, mangold (Beta vulgaris)		3050	40 Heavily thinned	1,628,022	840,000* ⁵
10 Beet, sugar (B. vulgaris)		4080	41 Moderately thinned	891,211	443,000* ⁵
11 Catalpa (Catalpa speciosa)	26,024	1,952,000	42 Pine (P. ponderosa), 2 yr old		72*
12 Coldenia (Coldenia hispiddissima)	11,560 ²	2300	43 Pine (P. resinosa), 27 yr old, 2x2 ⁶	19,439	77,900*
13 Corn (Zea mays)		7900	44 Pine (P. resinosa), 27 yr old, 4x4 ⁷	51,060	205,000*
14 Cotton (Gossypium sp)		535-1200	45 Pine (P. strobus), 27 yr old, 2x2 ⁶	121,805	149,000*
15 Crowbeard (Verbesina encelioides)		560	46 Pine (P. strobus), 27 yr old, 4x4 ⁷	186,644	228,000*
16 Cucumber (Cucumis sativus), 135 ft-c		16	47 Potato (Solanum tuberosum)		17,800
17 Cucumber (C. sativus), 270 ft-c		18	48 Raspberry (Rubus occidentalis), shoot		13,100
18 Cucumber (C. sativus), full sun		180-1100	49 Raspberry (R. occidentalis), fruiting cane		16,300
19 Date (Phoenix dactylifera), 12 yr old	120	525 sq m	50 Saltbush (Atriplex canescens)		47,000
20 Fir (Abies alba), trunk diameter 40 cm	15,000,000		51 Seepweed (Suaeda suffrutescens)		3210
21 Fir (A. pectinata)		12,000*	52 Sorghum, red amber (Sorghum vulgare)		4840
22 Frankenia (Frankenia jamesii)	9487 ²	2182	53 Spruce (Picea sp), 4 yr old	6577	550*
23 Gourd (Cucurbita foetidissima)	1617 ²	911,976	54 Strawberry (Fragaria chiloensis)		
24 Grape, malaga (Vitis vinifera)	32	4000-4900	55 Dunlap, with runners		1440
25 Grape, muscat (V. vinifera)	26	2300-2400	56 Dunlap, without runners		896
26 Milkweed (Asclepias arenaria)	36	1700	57 Strawberry (F. virginiana)		350
27 Morning glory (Ipomoea purpurea)	9 ²	750	58 Sumac (Rhus trilobata)	3000 ²	63,240
28 Oleander (Nerium oleander), 86 ft-c	24	268	59 Sunflower (Helianthus annuus)	59 ²	2260
29 Oleander (N. oleander), 300 ft-c	23	241	60 Taro (Colocasia antiquorum)	10	90,730
30 Orange (Citrus sinensis), 3 yr old	16,419	344,000	61 Wheat (Triticum aestivum), 600 ft-c	5	46-65
31 Orange (C. sinensis), 6 yr old	37,257	590,000			

/1/ Per stem. /2/ Calculated. /3/ Variety Crawford. /4/ Variety Elberta. /5/ Plants under artificial light, 600 ft-c. /6/ Plants, in experimental plots, spaced 2 ft x 2 ft. /7/ Plants spaced 4 ft x 4 ft.

This table is a summary of the salient topographic, ontogenetic, morphologic and functional characteristics of the most common types of cells in tical or experimental demonstration. Only approximate boundaries can be drawn between certain types of cells, and the occurrence of intergr differentiation when appropriately stimulated. Spores, gametes and many specialized cells (e.g., endodermal cells, secretory cells of glands,

Cell Type	Origin	Site
1 Apical meristem	Lineal descendants of cells of embryo except in adventitious shoots* and roots*.	Apices of vegetative shoots, developing inflorescences and flowers; in root beneath inner edge of root cap*.
2 Vascular cambial cells	From procambium* and from parenchyma in interfascicular areas, cortex*, and phloem*.	Lateral in stem and root, between secondary xylem* and secondary phloem*.
3 Phellogen (cork cambium)	In stems, first phellogen cells arise from cortex* (most commonly from outermost layer), or from epidermis or phloem* parenchyma cells; in roots from the pericycle*.	Lateral in stem and root, between phellem (cork) and subjacent phelloderm*, cortical or phloem* tissue; also beneath surfaces exposed by abscission of organs (e.g., leaf scars) or beneath wounds.
4 Epidermal cell	From the protoderm*.	The prevalent cell type in the surface layer (epidermis) of foliar and floral organs, young stems and roots.
5 Guard cells	Typically originate in pairs by the division of specific "mother cells" of the protoderm*. A pair of guard cells together with the intercellular space or pore between them is termed a <u>stoma</u> ; in many plants, the paired guard cells are flanked or surrounded by distinctive subsidiary cells.	An extremely consistent cell type in the epidermis of foliage leaves and young stems; occurs also rather commonly in the epidermis of various types of floral organs; absent from the epidermis of roots.
6 Phellem (cork)	From phellogen; in stems of some monocotyledons tangentially dividing cortical parenchyma cells produce irregular bands of suberized cells termed storied cork.	Peripheral regions of stem, root and certain types of fruits; occurs in some bud scales and petioles; often produced as a result of wounding.
7 Parenchyma	From ground meristem*, procambium*, vascular cambium and phellogen.	Widely distributed throughout plant body; commonly the dominant cell type in cortex*, pith*, mesophyll*, fleshy fruits and the endosperm* of seeds; occurs in phloem* and xylem* as the component of vertical parenchyma strands and vascular rays*.
8 Collenchyma	From ground meristem*.	The sole component of cylinders or strands of tissue in the subepidermal portions of stems, petioles and the larger veins of leaves; may occur in cortex* of roots.
9 Sclereid	From protoderm* (e.g., in developing seed coats), ground meristem*, phellogen, vascular cambium and procambium*; frequently arises by sclerosis* of a fully developed parenchyma cell.	Common in seed coats and fruits; diffusely arranged in cortex*, functioning phloem*, outer bark, pith* and mesophyll* as idioblast* or as component of cell clusters; in leaves of some dicotyledonous genera restricted to vein endings (terminal sclereids).
10 Fiber	From protoderm*, ground meristem*, procambium* and vascular cambium.	Cortex*, primary and secondary vascular tissues of stem and root; epidermis of certain leaves; a component of the hypodermal strands or layers and the sclerenchymatous* sheaths of vascular bundles* in many kinds of leaves; may occur as an idioblast*.
11 Tracheid	From procambium* and vascular cambium.	Primary and secondary xylem*; in a modified form, the distinctive cell type in the transfusion tissue* of gymnospermous leaves; tracheid-like cells occurring as idioblasts* or components of cell layers or groups in angiospermous leaves are termed "storage tracheids"; commonly formed in masses in cultures of callus* tissue.
12 Vessel member	From procambium* and vascular cambium.	Primary and secondary xylem* of most dicotyledons; absent from xylem* of all gymnosperms except members of the Gnetales; in certain monocotyledons, restricted to the primary xylem* of the root.
13 Sieve cell	From procambium* and vascular cambium.	Primary and secondary phloem* of gymnosperms.
14 Sieve-tube member	From procambium* and vascular cambium.	Primary and secondary phloem* of angiosperms.
15 Laticifers	Non-articulated type from a single initial cell which develops into a continuous tube often ramifying throughout the plant; articulated type from an interconnected and progressively developed series of cells in which occurs a complete or partial resorption of certain cell walls.	Cortex*, phloem*, xylem rays*, pith*, mesophyll*.

GLOSSARY: ADVENTITIOUS SHOOT: A shoot arising from internodal regions of the stem, from roots, leaves, or from callus. ADVENTITIOUS wound-surfaces of stems, petioles, and roots. CORTEX: The zone of primary tissues situated between the epidermis and the vascular cylinder meristems or to different cell types. ENDOSPERM: Food-storing parenchymatous tissue in seeds, sometimes with massively-thickened cell dual cell which differs markedly in form, size, wall structure or contents from neighboring tissue-elements. LENTICEL: A small restricted MESOPHYLL: The photosynthetic parenchyma tissue of the leaf enclosed by the epidermis. PERICYCLE: The uniseriate or multiseriate zone suberized walls produced inwardly by the phellogen. PHLOEM: One of the tissues of the conductive or vascular system of the plant body; the cell, usually paired with a similar cavity in the adjacent cell; such pit-pairs are separated from each other by a common pit membrane. PRESSIONS in the primary walls of plant cells traversed by groups of protoplasmic strands or plasmodesmata; one or more pits may develop over primary vascular system (primary phloem and primary xylem) originates. PROSENCHYMATOUS: A term designating a cell which is conspicuous; in some cases, cells internal to the epidermis may also originate from the protoderm. ROOT CAP: A thimble-shaped or conical mass of because of the presence of thick, usually lignified cell walls. SCLEROSIS: The process whereby a parenchyma cell acquires a thick lignified sec-TISSUE: A tissue composed of relatively short, broad tracheids which flanks or surrounds the vascular bundles in gymnospermous leaves; in ening tissue composed primarily of phloem and xylem. VASCULAR RAY: A radial band or sheet of parenchyma cells produced by the division phloem is a phloem ray; the two are continuous. XYLEM: One of the tissues of the conductive or vascular system of the plant body; the definitive

CELL TYPES: SEED PLANTS

seed plants. The typology adopted for the table reflects individual interpretation of morphologic data and hence is not subject to rigorous statistical analysis. The typology is indicated at several points in the table. Moreover, many types of living cells are capable of growth, division and further structural changes (e.g., cells of resin ducts, cells of hairs) have not been included. Terms followed by an asterisk (*) are defined in the Glossary below.

Morphology	Functions	
Polyhedral; primary wall thin or irregularly thickened; primary pit fields* may be present; nucleus large, ovoid; cytoplasm vacuolated to varying degrees; mitochondria, plastid primordia and storage products may be present.	Point of origin of primary meristematic tissues, e.g., protoderm*, ground meristem* and procambium* from which primary body of shoot and root develops; in shoot apex, gives rise to the tissue of a leaf primordium.	1
Two types of cambial cells, viz.: elongate fusiform initials, from which tracheary elements, sieve elements, fibers and vertical parenchyma are derived, and ray initials, from which vascular rays* originate; cytoplasm of both kinds of initials highly vacuolated; primary walls with conspicuous pit fields.	Produce secondary phloem* and secondary xylem* cells. Growth in diameter of woody stems and roots results from tissue-formation by cambial cells.	2
Rectangular and radially flattened in transverse view, polygonal or nearly isodiametric in longitudinal section; walls thin; cytoplasm vacuolated; may contain tannins and chloroplasts.	Produce phellem cells outwardly and in many cases, phelloderm cells* inwardly; forms complementary cells of lenticels*.	3
Polygonal, elongated or with undulate contour in surface view, variable in radial dimensions; walls thin or thick, the outer wall often the thickest; primary pit fields* present; walls typically cutinized (may be lignified or silicified), the outer wall covered by a cuticle except in roots; plastids, anthocyanin pigments and ergastic substances may occur.	Mechanical protection; restriction of transpiration; storage of H ₂ O and metabolic products; photosynthesis; H ₂ O absorption in roots; by division and dedifferentiation* may contribute to origin of adventitious shoots* and roots*.	4
Usually crescentic or kidney-shaped in surface view; walls unevenly thickened, cutinized and overlaid by a cuticle; often with ridge-like extensions above and below the pore; conspicuous starch-forming chloroplasts present; protoplast physiologically active in mature cells but rarely divides in response to wound or other stimuli.	Stomata are the important points of diffusion of gases through the epidermis. Reversible changes in turgor of guard cells result in the opening or closure of the pore.	5
Rectangular in transverse section and more or less radially flattened; irregular or rectangular in longitudinal section; secondary wall typically suberized and occasionally lignified; pits absent; devoid of protoplasm at maturity.	Mechanical protection; restriction of transpiration.	6
Varies widely in shape from approximately tetrahedral to elongated or stellately branched; primary walls thin or thick, often with conspicuous pit fields; thick lignified secondary walls with pits* common in parenchyma cells of secondary xylem*; plastids and a wide range of ergastic substances present.	Photosynthesis; food and H ₂ O storage; secretion and excretion; commonly the protoplast retains marked capacity for growth, division and dedifferentiation* and hence prominently concerned in wound healing, formation of callus* tissue, and the origin of adventitious shoots* and roots*.	7
Relatively short and prismatic or elongated with tapering ends; primary walls unevenly thickened, composed of cellulose and pectin and with high percentage of H ₂ O; primary pit fields present; chloroplasts common; collenchyma and cortical parenchyma cells frequently intergrade in form and structure.	Mechanical support for growing stems and leaves; protoplast retains capacity for growth, division and dedifferentiation*.	8
Form extremely variable: polyhedral, columnar, fusiform, filiform, irregularly lobed or profusely branched; in some cases intergrades in form with fibers; secondary wall thick and lignified (sometimes with embedded crystals); pits* usually simple, often ramiform; protoplast may be retained at maturity.	Produce hard incompressible texture of many tissues.	9
Typical example of a prosenchymatous* cell, often reaching considerable length; secondary wall usually thick, often highly lignified; pits* abundant or sparse, simple or with greatly reduced borders; protoplast usually absent at maturity; a living protoplast and various ergastic materials occur in separate fibers; in secondary xylem* of dicotyledons, fibers and tracheids frequently intergrade in form and structure.	Mechanical support.	10
Typically elongated, with blunt, tapering or inclined ends; imperforate at maturity; secondary wall lignified, deposited in a wide variety of frequently intergrading patterns, i.e., as rings, one or several helical bands, transverse or oblique bars, a network, or as a continuous layer interrupted only by bordered pits*; devoid of protoplast at maturity.	Conduction of H ₂ O and mineral solutes; mechanical support.	11
Elongated to drum-shaped, with inclined or transverse perforated end walls; developed as a component member of an extensive series of superposed cells termed collectively a vessel; perforations usually restricted to end walls and are either single (simple perforation plate) or multiple (scalariform, reticulate and foraminiform types of perforation plates); secondary wall lignified, with same range of patterns as in tracheid; devoid of protoplast at maturity.	Conduction of H ₂ O and mineral solutes; and possibly mechanical support.	12
Elongated in form with overlapping inclined or tapering ends; sieve areas numerous, all similar and relatively unspecialized in structure; each sieve area is a portion of the primary wall traversed by connecting strands of cytoplasm enclosed by cylinders of callose; protoplast at maturity enucleate, devoid of stainable contents and starch; usually connected with modified parenchyma cells termed albuminous cells.	Conduction of organic solutes.	13
Elongated in form with inclined or transverse end walls; developed as a component member of a series of superposed cells termed collectively a sieve tube; end walls with highly specialized sieve areas termed sieve plates; sieve plates simple (one sieve area) or compound (many sieve areas); lateral walls usually bear less specialized sieve areas; protoplast at maturity enucleate and devoid of stainable contents and starch; usually connected with one or more nucleated parenchyma cells termed companion cells, the latter ontogenetically developed as sister cells of the sieve-tube member.	Conduction of organic solutes.	14
Contain latex and are multi-nucleate; primary walls often relatively thick in mature tubes; non-articulated type an unbranched or very often a profusely branched tube; vertical series of articulated laticifers may become joined by lateral anastomoses into a complex network.	Probably excretory because of storage of such apparently non-functional metabolic products as rubber and resin; role of laticifers as food conducting and food storing structures doubtful.	15

ROOTS: Roots arising from stems, leaves, or from callus. **CALLUS:** Tissue composed of parenchyma which originates by proliferation from in roots and stems. **DEDIFFERENTIATION:** The process by which living physiologically mature cells resume growth and division, giving rise to new cells. **GROUND MERISTEM:** The undifferentiated tissue of a young organ exclusive of the protoderm and procambium. **IDIOBLAST:** An individual cell of loosely-arranged cells situated in the periderm; the latter consists of the phellem (or cork), the phellogen, and the phelloderm. **PHELLODERM CELLS:** Parenchymatous cells with undifferentiated conductive cell types in the phloem are the sieve cell and the sieve-tube member. **PIT:** A cavity or recess in the secondary wall of a cell. **PITH:** A central column of tissue in the stem and in certain roots, bounded externally by the vascular cylinder. **PRIMARY PIT FIELDS:** Devoid of pit field if a secondary wall is formed. **PROCAMBIUM:** Undifferentiated tissue composed of more or less elongated cells from which the secondary wall is formed. **PROTODERM:** The undifferentiated surface cell layer of young organs from which the epidermis develops. **PROTODERMIS:** Undifferentiated tissue occupying the true apex of the root. **SCLERENCHYMATOUS:** A term designating cells or tissues which are hard or tough. **TRANSFUSION PIPES:** Living parenchyma cells as well as tracheids occur in the transfusion tissue. **VASCULAR BUNDLE:** A strand of conducting and strengthening elements in the vascular cambium. That portion of a vascular ray found in the secondary xylem is a xylem ray; that portion in the secondary phloem is a phloem ray. **XYLEM RAY:** See Vascular Ray.

124. TISSUE GROWTH CHARACTERISTICS:

Part I:

Tissue		Cell Division in Postnatal Life	Mode of Postnatal Growth
1	Adrenal	Mitosis adult rat: zona capsula, 0.13%; zona glomerulosa, 0.17%; zona fasciculata, 0.13%; zona reticularis, 0.06%; total gland, 0.12%. Considerably higher figures in young rat.	Principally by cell division. Capsule may contribute.
2	Alimentary canal	Dividing cells in crypts of duodenum and ileum. In rat, make up 3% of all cells; cycle, 1.13 hr. In stomach, dividing cells at base of foveolae.	Cell division and differentiation in mucous membrane. Muscle, by combination of cell division and increase in cell size.
3	Blood erythrocytes	Confined largely to erythroblasts in bone marrow; dividing cells in man, 1.17-1.83%.	In precursors, growth phase sharply separated from phase of hemoglobin formation.
4	Blood granulocytes	Confined largely to myeloblasts (2.7%) and myelocytes (0.46%) in bone marrow.	Growth stages sharply demarcated from the stages of granule formation.
5	Blood lymphocytes	In tissues of origin. Dividing cells in 3 mo rat: thymus, 0.22%; lymph nodes, 0.058%; lymph follicles in spleen, 0.058%.	Derived from reticulum cells and may be converted to other forms, but this is disputed. In dog, 25 times 10^6 /kg/hr enter circulation; in cat, 35 times 10^6 .
6	Blood platelets	Division of circulating platelets not described.	Evidence favors formation in marrow from cytoplasmic fragmentation of megakaryocytes.
7	Brain and spinal cord	Very rare but has been recorded.	Growth of axones; myelization of fiber tracts; may not be completed until 18th yr in man.
8	Heart	Negligible in cardiac muscle.	Increase in size of muscle fibers. In rabbit, from birth to maturity, diameter of fibers increases times 2.6 (to 19 μ); in man, times 2.6 (to 14 μ).
9	Kidney	Rare after early postnatal life except for regeneration in rodents. birth to maturity, diameter of glomerulus increases from 118-240 μ ; of proximal collecting tubules, from 18-34 μ to 40-64 μ . In rat, early postnatal growth partially caused by peripheral undifferentiated nephrogenic zone; number of nephrons doubled in first two weeks of postnatal life.	Increase in size of cells and structures. In man, from birth to maturity, diameter of fibers increases times 2.6 (to 19 μ); in man, times 2.6 (to 14 μ).
10	Liver	In rat, dividing cells rise from low values to 3.3% on 23rd da, then return to low values; mitotic percentage in adult albino rat, 0.005%.	In early life, considerable contribution from cell division; later, from increase in cell size.
11	Muscle, striped	Very scant and confined to nuclei. Some amitotic divisions.	Enlargement of fibers, possible splitting of fibers. In newborn, some continued formation from mesenchyme cells. Hypertrophy caused by increase of sarcoplasm in pre-existing cells.
12	Ovary	Mitosis demonstrated in germinal epithelium and, during early pregnancy, granulosa and theca interna cells.	In rabbit, follicles increase in size exponentially with time; completed in 18 da; total number of oocytes in gland related to age: $\log(\text{number}) = 4.561 - 0.476 \log(\text{age in da})$.
13	Pancreas; submaxillary		Decrease of relative amount of connective tissue after birth; adult proportions reached at 11th-16th yr.
14	Parathyroid	Dividing cells in mice: 8 da, 0.07%; 18 da, 0.71%; 28 da, 0.1%.	Multiplication of clear or stem cells which differentiate into "dark" cells.
15	Prostate	In rat, mitosis numerous to 20th da; scant at 100 da. cell size and diameter of acini. From 11-55 da height of cells increases from 18-34 μ , and diameter acini from 43-170 μ . Growth affected by hormonal activity. In man, some squamous metaplasia in newborn.	In rat, by cell proliferation to 20th da, then by increase of cell size and diameter of acini.
16	Skin	Occurs in varying proportions in stratum basalis and spinosum. In adult mice, 2-8 dividing cells/cm length of 7 μ ear section; duration of mitotic cycle, 2.5 hr. Number of divisions varies with time of da, carbohydrate metabolism, hormonal stimuli, etc. In newborn mice, 2-4% of nucleated cells in mitosis. Mitotic percentage in the planta of the rat (250g) averages 5.24% for 24 hr at 27°C.	Division of cells in deeper layers followed by differentiation.
17	Testis	In albino rat, cycle of spermatogonial division, 48 min. Spermatogenic wave lasts 4 da; spermatogenic cycle takes 16 da.	
18	Thymus	Mitosis: adult rabbit, 0.52%; 3 mo rat, 0.22%.	Weight in man: birth, 12g; puberty, 40g; 60 yr, 15g.
19	Thyroid	100-125 dividing cells recorded in whole gland of guinea pig. proliferation of undifferentiated interfollicular cells.	Following possibilities described: new follicles by budding; proliferation of cells derived from follicles.
20	Uterus		Pregnancy: enlargement of pre-existing epithelial cells, glands and muscle fibers; cell division of epithelial and muscle elements in addition; new muscle fibers may form from indifferent cells. Menstruation: in proliferative phase mitosis in endometrium rises 0.56% and nuclei of muscle fibers increase in size; regression of secretory phase: denuded surface covered in 7 da by cells from remaining glands.

/1/ In peripheral nerves.

Part II: INCREMENTS OF WEIGHT

Each value is derived from the weight at the end of a time period

Tissue	Prenatal Period ¹			Birth to Adult	Tissue	Prenatal Period ¹			Birth to Adult
	8-12 wk	12-16 wk	20-24 wk			8-12 wk	12-16 wk	20-24 wk	
1 Brain	15	4.5	1.7	3.7	4 Liver	17	3.6	1.8	18
2 Heart	6.5	4.3	1.9	15	5 Muscle, striped				30-40
3 Kidney	75	6.7	1.6	10	6 Ovary				37

/1/ 280 da.

VARIOUS ANIMALS

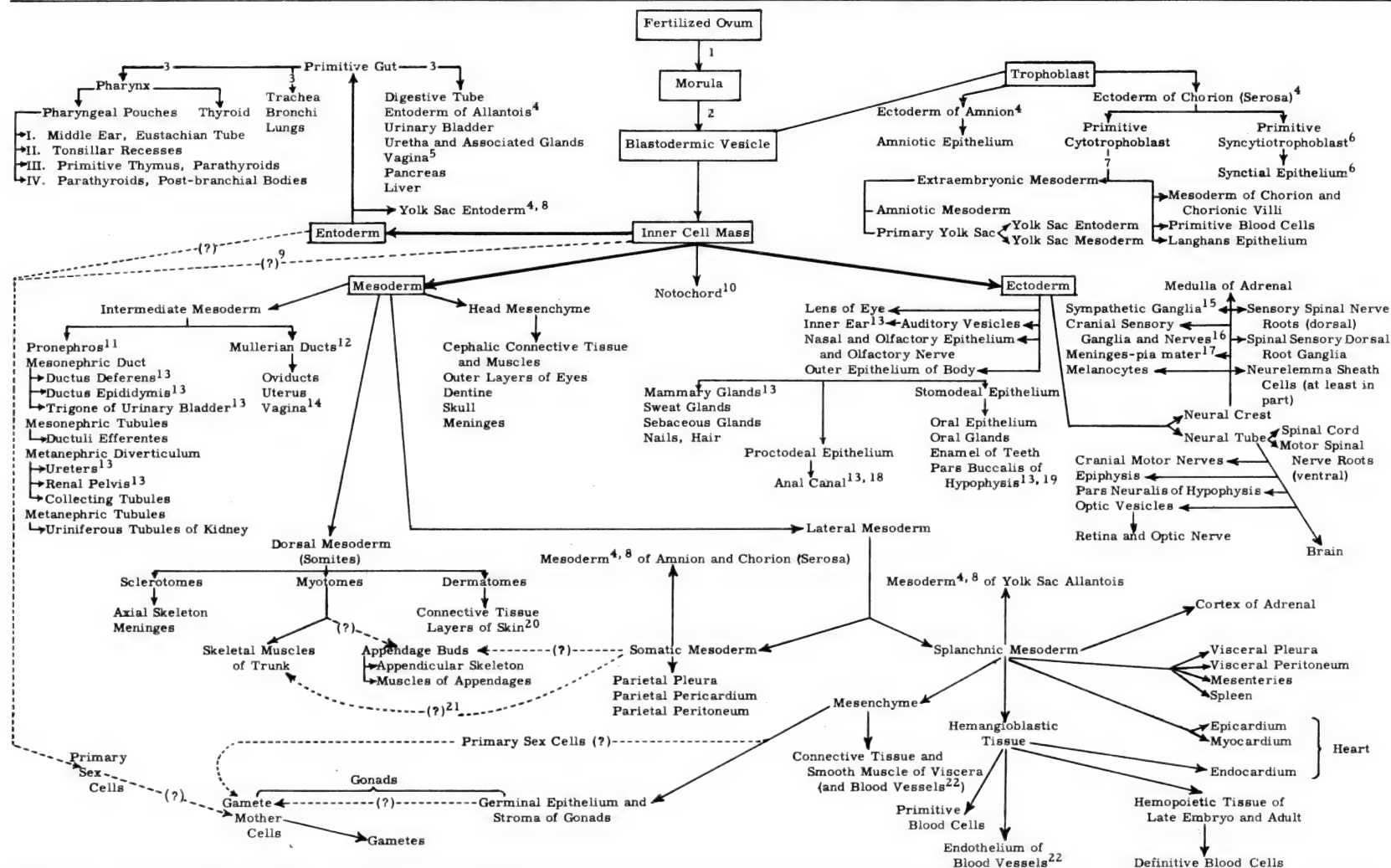
GENERAL

Life Span of Cells	Mechanism of Cell Replacement	Regenerative Capacity	
In cortex, uncertain but phagocytosis occurs in zona reticularis.	In cortex, cell division and migration of cells from superficial to deeper layers.	In cortex, after damage, repair by cell division but limited in adult. Active regeneration follows postnatal degeneration. Mitosis very scanty in medulla; postnatal growth from cell enlargement.	1
In small intestine, rat: 60-70% superficial epithelium shed/da; cell lives 1.57 da in duodenum, 1.35 da in ileum. Oral mucosa, rabbit, 5.1(4.5-5.7)/1000 cells [diurnal variation 3.8(3.6-4.0) and 7.2(6.6-7.8)]. Mitotic duration calculated as 64 min. Intermitotic period calculated as 208 hr.	Cells multiply in crypts in base of foveolae, move toward lumen and differentiate.	After removal of mucous membrane in dog's stomach, denuded area covered by growth of undifferentiated epithelium at rate of 2 mm/wk. Healing in 10 da if muscularis mucosae intact, 130 da if muscle destroyed. Brunner's glands can undergo limited regeneration. Cat's stomach: movement at 0.2-0.4 mm/hr; sudden loss of epithelium made good in a few hr.	2
120 da most generally accepted.	See Mode. In man, 0.83% red cells replaced each da.	In rabbit, recovery from 30% blood loss, 3 wk; in rat, 7 da. In man, recovery from loss of 600 ml, 50 da.	3
Neutrophils estimated at 7-80 hr; disappear from blood of cat at rate of 881/cu mm/hr.	Eosinophils, 10-14 da.	Replaced 1.5 times/da in cat.	4
Approximately 24 hr. Removed from blood by lungs, spleen, lymph glands, skin, intestine.	See Mode. Replacement in blood stream about twice a day.	Limited regeneration of lymph nodes after removal in young rabbits; mesenchyme cells form complete gland in 3-4 wks.	5
In cat, 2-4 da; utilization at rate of 2500/cu mm blood/hr.	After loss, new formation begins in a few hr. Normal regained 3-4 da.		6
Coextensive with normal function.	Confined to neuroglia.	Very largely confined to neuroglia; some axone formation. Regeneration of motor axones occurs at 4 mm/da after latent period of 7± da. A large number of factors affect rate. Preganglionic fibers ¹ of cat regenerate in 36-61 da; function restored in 44 da.	7
Coextensive with normal function.	None.	Negligible. Hypertrophy caused by increase in size of fibers. Rabbit: normal diameter, 19.2μ; hypertrophied, 22.2μ; man, normal, 14μ; hypertrophied, 25μ.	8
Very largely coextensive with normal function.	By cell division in tubules.	True regeneration observed in rats. Hypertrophy caused by enlargement of existing elements, but increased cell division has been demonstrated after unilateral nephrectomy in the rat.	9
No figure quotable.	Dividing cells persist in small numbers in adult presumably to replace cell loss.	In rat, extirpation of 2/3 regenerated in 21 da, caused by cell division in the parenchymal cells, and to a smaller extent in duct cells. Division also occurs in Kupffer cells and connective tissue cells.	10
Coextensive with normal function.	Normally none.	Protoplasmic outgrowth from pre-existing fibers in which nuclei may divide by amitosis. Outgrowth begins 3rd da after injury, progresses at 1-1.5 mm/da. New fibers 30% normal diameter in 21 da; normal diameter in 4 mo. No new formation from indifferent cells.	11
Fertility of shed ova lost: rabbit, 12 hr; guinea pig, 26 hr; ferret, 30 hr.		No regeneration of ova but marked regeneration activity of germinal epithelium after hormonal stimulation.	12
		Limited amount after resection or duct ligation. Mitosis in acinar cells and duct epithelium, the latter giving rise to acinar cells and islet cells. In rat, submaxillary gland regeneration by division of acinar cells in 1st week, followed by proliferation of ducts with acini formed with terminal portions.	13
		Negligible. Hypertrophy and hyperplasia in chronic nephritis.	14
	Regeneration after surgical removal very rare in man.		15
Variable and dependent on rate of shedding of keratinized cells. Plantar epidermis cells of rat 19.1 da, of which 16.9 da are spent in basal layer and 2.2 da in stratum granulosum. Mitotic index: in corneal epithelium, rat (80-150g), 0.4%.	See Mode. Adjustment between cell loss and cell formation.	Re-epithelization of wounds by proliferation and migration of adjacent cells. Regeneration possible from hair follicles. Rate of healing greater in larger wounds. Growth of granulation tissue checked by epithelial overgrowth. Nails (man): growth 95μ/da (thumb). Fingernail growth 4 times toenail. Hair: length of cycle depends on thickness. Man: head, 3 yr; eyebrow, 120 da. Body of rat, 35 da. Rate of growth (man) varies with site (mm/wk): head, 2.7; arm, 1.5; face, 2.1-3.5.	16
Sperm survival time: in man, 48-72 hr; horse, 12 hr; mouse, 13.5 hr; rabbit, 96 hr; some bats may overwinter.	Replacement by multiplication and differentiation of cells at bottom of hair follicles.	Possible after slight injury. In rabbit, 1 da in abdominal cavity causes loss of spermatogenic elements, with restoration in 2 wk.	17
		After partial removal, hypertrophy of remainder preventable by iodine administration.	18
		Experimental incision in mouse heals in 48 hr without scar. Smooth muscle fibers retain some power of division; new formation possible from undifferentiated connective tissue cells. Regeneration (smooth muscle) after injury limited, and fibrous scar usual.	19
			20

INCREASE: MAN

divided by the weight at the beginning of the same time period.

Tissue	Prenatal Period ¹			Birth to Adult	Tissue	Prenatal Period ¹			Birth to Adult
	8-12 wk	12-16 wk	20-24 wk			8-12 wk	12-16 wk	20-24 wk	
7 Pancreas	Av 16	Av 16	1.6	20-40	10 Thymus	400	3.7	1.9	
8 Pituitary	2.5	3	1.7	3-6	11 Thyroid		6.6	2.2	14
9 Adrenal cortex	25	5	1.7		12 Uterus				27



1/ By cleavage divisions. 2/ By hollowing out and expansion. 3/ Epithelial portion of the structure from entoderm, remainder from mesoderm. 4/ Extraembryonic, i.e., part of the placenta or other extraembryonic membranes. 5/ Lower part. 6/ Variable, not present in all mammals. 7/ In primates only. 8/ Probably not in primates. 9/ Embryonic structure. May form nucleus pulposus of intervertebral discs. 10/ Embryonic structure; disappears. 11/ Or from splanchnic mesoderm of peritoneum. 12/ Epithelial portion of the structure from ectoderm remainder from mesoderm. 13/ Upper part. 14/ Absolute derivation of neural crest on disputed grounds. 15/ Evidence from lower vertebrates that a portion of these may be derived from ectodermal placodes. 16/ Probably only part of pia mater, not dura or arachnoid. 17/ In part only. 18/ Anterior lobe and pars intermedia of the pituitary. 19/ In region of somites only. 20/ Ventral and lateral part, evidence from chick only. 21/ Not all from splanchnic mesoderm; some from somatic mesoderm or head mesenchyme.

126. PRENATAL DEVELOPMENT, REFLEX AND SPONTANEOUS MOTOR ACTIVITIES: MAMMALS

This table gives no clue to the combination of activities constituting a single response, except that activities reported as observed at the same gestation age may, in some instances, form a response pattern. Unless otherwise indicated (as "spontaneous"), each response is to be considered an induced exteroceptive reflex.

Motor Activity	Gestation Period, % ¹					Motor Activity	Gestation Period, % ¹				
	Man ²	Cat ³	Guinea Pig ⁴	Rat ⁵	Sheep ⁶		Man ²	Cat ³	Guinea Pig ⁴	Rat ⁵	Sheep ⁶
1 Earliest spontaneous ⁷ activity ⁸	22.5	36	40		22.3	36 Rump					
2 Earliest proprioceptive activity ⁸	18.7-23.8				21.6-28 ⁹	36 Extension	26	52	55	81	
3 Appearance of earliest and latest exteroceptive reflexes ¹⁰	18.7-80	26-74	38-76	75-90	26-57 ¹¹	37 Lateral flexion		41	49	76	
Head						38 Ventral flexion		39-48 ¹⁷		77	
4 Extension	26	42	48	76-79	26	39 Rotation	21.2	47		81	
5 Lateral flexion at neck	18.7	37-38	48	76	23-29 ¹²	40 Upper extremity					
6 Ventral flexion	32	36-42	52		35	40 Movement with trunk	21.2	37		76	
7 Rotation	28	36-42	51	76	24.8-26 ¹²	41 Adduction at shoulder		50	48		
Face						42 Abduction at shoulder	29	33			23-26 ¹²
8 Forehead movements	28		60			43 Extension at shoulder	21.2	39	39	75 ¹⁶	26
9 Palpebral muscle movements	28		54			44 Flexion at shoulder		35-39	39		26
10 Eyes, movement globus oculi	31		58		32 ⁷	45 Rotation, medial	28				
11 Oronasal muscle movements	31	39	58	90	32	46 Elbow extension	30	38			24.8 ⁷
12 Lip movements	31		54			47 Elbow flexion	28	39	48	81	24.8-28 ¹²
13 Mouth closing	31		54	90	26	48 Forearm pronation	28				
14 Mouth opening	23.8		52	77	26-32 ¹²	49 Wrist extension		58 ¹⁶		86	
15 Mouth pursing	55					50 Wrist flexion	28	38-48	48	75-81 ¹⁷	
16 Tongue movements	35	44-56	55	77		51 Pollex flexion	26				
17 Sucking	72 ¹³	74	55		31	52 Pollex opposition	32				
18 Swallowing	30				51	53 Finger flexion	26		54		
19 Phonation	59 ¹³	74				54 Finger closure, maintained	38				
Neck						55 Grasp	46				
20 Extension	26		39		24.2-35 ¹²	56 Lower extremity					
21 Lateral flexion	18.7		39	76	29	56 Movement with trunk				77	
22 Ventral flexion			38		26	57 Scratch reflex			54		57
Trunk						58 Adduction at hip			67		
23 Rotation or twisting	35	39-41	54	81		59 Abduction at hip		38-45 ¹⁷			
24 Chest contractions, respiratory	30-32	50			24.2-31 ¹⁴	60 Extension at hip	29	24.2-47 ¹²	51	81	
25 Diaphragmatic contractions, resp.	55	67			24.2 ⁷	61 Flexion at hip	28	42-45	48	86	26
26 Effective respiration	59 ¹³					62 Rotation, lateral	28				
27 Abdominal muscle contractions	38	42-50	46-58 ¹²	81		63 Rotation, medial	28				
28 Cremasteric reflex	80		76		50	64 Knee extension	32				24.8 ⁷
29 Tail movements		42-47		86		65 Knee flexion	29	44-58 ¹⁷			24.8 ⁷
Upper trunk ¹⁵						66 Ankle adduction		68 ¹⁶			
30 Extension	26	42	45			67 Ankle dorsiflexion	29				24.8 ⁷
31 Lateral flexion	20	36-39	40-46 ⁷	75-76 ¹⁶	23-26 ¹²	68 Ankle plantar flexion		61			24.8 ⁷
32 Ventral flexion		38	43	77	24.2 ⁷	69 Ankle rotation		68 ¹⁶			
33 Lower trunk ¹⁵						70 Hallux dorsiflexion	34				
Extension	26	42	45	76		71 Hallux plantar flexion	28				
34 Lateral flexion	21.2	39	40-46 ⁷	75		72 Toe fanning	34				
35 Ventral flexion		38	43	77	24.2 ⁷	73 Toe dorsiflexion	34	73 ¹⁶			
						74 Toe plantar flexion	28	73 ¹⁶			

/1/ Per cent of gestation period = per cent of total gestation period elapsed at the time the motor activity appears. The gestation period is measured from the time of insemination except for man, in which case measurement is from the first day of the last menstrual period. To convert, in the case of man, to per cent of gestation period on insemination age, the following equation may be employed:

$$\text{Corrected per cent} = \frac{(\text{given per cent} \times 40) - 200}{38}$$

/2/ Gestation period = 280 da measured from the beginning of last menstrual period; corrected = 266 da from ovulation. /3/ Gestation period = 66 da

(see Fn 1). /4/ Gestation period = 67 da (see Fn 1). /5/ Gestation period = 21 da (see Fn 1). /6/ Gestation period = 157 da (see Fn 1). /7/ Spontaneous activity; believed to be essentially reflex in mammals. /8/ Unspecified. /9/ Doubtful reflex at the lower limit of this range. /10/ Complex patterns of behavior; behavior released by the head exteroceptors not included. /11/ Doubtful reflex at 22.3% of gestation period. /12/ See Fn 7; the qualification applies only to the lower limit of this range. /13/ Human fetus viable at 68% of gestation period (27 wk). /14/ Spontaneous activity at 26% of gestation period. /15/ Data for guinea pig do not distinguish between movements of the upper and lower segments of the trunk. /16/ Movement is reported without specific data as to direction of movement. /17/ See Fn 16; the qualification applies only to the lower limit of this range.

127. PRENATAL DEVELOPMENT, VARIOUS ORGANS AND TISSUES: CHICK

Time of origin is expressed in three ways, depending on available information: (1) days or hours of incubation, (2) number of pairs of somites, or (3) normal "stages" as described by Hamburger, V., and Hamilton, H. L., J. Morphology 88:49, 1951. Data adapted from Lillie's "Development of the Chick," Henry Holt & Co., 1952. Footnotes refer to onset of function only.

Organ or Structure	Time of Origin	Site of Origin	Organ or Structure	Time of Origin	Site of Origin
1 Abducens nerve	3rd da	Floor of myelencephalon beneath nerve VII.	78 Hindgut	21 s	In splanchnopleure, with appearance of tail fold.
2 Acrochordal cartilage	4½ da	At anterior tip of notochord.	79 Hypoglossus (Cranial nerve XII)	78 hr	From ventral part of neural tube opposite somites 3-4.
3 Acoustico-facialis ganglion		Anterior edge of auditory pit.	80 Hypothalamus	97 hr	Ventral wall of diencephalon.
4 Facial component	By stage of 15 s	From neural crest and posterodorsal epibranchial placode of 1st visceral furrow.	81 Interatrial septum	50-55 hr	From vault of atrium between openings of sinus venosus and pulmonary vein.
5 Acoustic component	21 s	From wall of auditory vesicle.	82 Interstitial cells	13th da	In stroma of testis.
6 Adrenal gland	78 hr	Coelomic epithelium at level of somites 17-22.	83 Interventricular septum	4th da	Along sulcus from bulbo-atrial angle towards apex of heart.
7 Cortical component	4-7 da	From migratory cells of neural crest and sympathetic ganglia.	84 Islets of Langerhans ¹¹	8-9 da	Within pancreatic diverticula.
8 Medullary component			85 Jaw, upper	4-5 da	Fusion of fronto-nasal and maxillary processes.
9 Air sacs of lung ²			86 Jugal bone	9th da	Skull.
10 Primary bronchi and mesobronchi	4 da	Posterior end of trachea.	87 Jugular lymph sac	7 da	Fusion of lymphatic vessels near anterior cardinal vein.
11 Entobronchi (secondary bronchi)	6th da	Mesial wall of anterior part of mesobronchus.	88 Labial groove	Stage 36 (10 da)	In periderm of tip of jaws.
12 Ectobronchi (secondary bronchi)	6th da	Dorsal surface of middle part of mesobronchus.	89 Laryngotracheal groove	23 s	Postbranchial floor of pharynx.
13 Parabronchi (tertiary bronchi)	8-11 da	From secondary bronchi.	90 Leg bud	50-60 hr (Stages 16-17)	Somatopleure lateral to posterior-most somites and segmental plate.
14 Allantois	28 s	Floor of hindgut just anterior to anal plate.	91 Lens invagination	20-21 s	Ectoderm overlying optic vesicle.
15 Amnion (and Chorion) ³			92 Lingual glands	11 da	From oral epithelium beneath lateral margin of tongue.
16 Anterior amniotic fold	8-9 s	Anterior edge of proamnion (in front of head).	93 Liver ¹²	22 s	Diverticula of the entoderm of the anterior intestinal portal.
17 Posterior amniotic fold	27 s	From somatopleure posterior to tail.	94 Lungs ²	23 s	Postbranchial floor of pharynx.
18 Aorta, dorsal ⁴	5 s	From hemangioblasts at ventrolateral margin of somites.	95 Mandible, ossification	9th da	
19 Aorta, ventral	3-5 s	From hemangioblasts continuous anteriorly with primordia of heart.	96 Mandibular glands	8th da	Solid ingrowths of mucosa from base of tongue forward to near mandibular symphysis.
20 Aortic arch 1 ⁴	9-10 s	Anterior to hyomandibular cleft.	97 Mantle layer of spinal cord	3rd da	From middle zone of neural tube.
21 Aortic arch 2	19-24 s	Posterior to hyomandibular cleft.	98 Maxilla (bone)	9th da	
22 Aortic arch 3	26 s	Between visceral clefts 2 and 3.	99 Mesenteric vein	5th da	In dorsal mesentery, near level of dorsal pancreas.
23 Aortic arch 4 ⁵	36 s	Between visceral clefts 3 and 4.	100 Mesenteries, accessory	60 hr	Mesenchymatous outgrowths of splanchnic mesodermal covering of lateral wall of esophagus.
24 Aortic arch 5 ⁵	4th da	Just anterior to aortic arch 6 and attached to the base and summit of arch 6.	101 Mesocardia, lateral	10 s	At point of contact of somatopleure with proximal part of vitelline veins.
25 Aortic arch 6	4th da	Behind 4th visceral cleft.	102 Mesonephric tubules ¹³	29-30 s	From nephrotome between somites 13-14 and 30.
26 Auditory ossicles	5-6 da	From mesoderm above dorsal extremity of tubotympanic cavity.	103 Mesothalamus	97 hr	Lateral wall of diencephalon.
27 Basioccipital bone	After 13 da	Skull.	104 Metanephric tubules ¹⁴	7-8 da	Metanephrogenous blastema just behind level of umbilical arteries.
28 Beak	5 da (Stage 27)		105 Nares, external and internal	4-5 da	By fusion of median and lateral frontonasal processes with maxillary processes of visceral arch I.
29 Blood cells			106 Nasal bone	9th da	
30 Granulocytes	3 da		107 Nasal (olfactory) pits	Stage 17	Ectoderm of ventrolateral sides of head opposite telencephalon.
31 Neutrophils	5 da		108 Neostriatum	8-12 da	Telencephalic cortex.
32 Eosinophils	7 da	Spleen (?).	109 Neural crest	6-7 s	In head.
33 Basophils	14 da	Spleen (?).	110 Neural folds	Stages 6-7	Anterior end of medullary plate.
34 Lymphocytes	17 da	Spleen and other lymphatic areas.	111 Neural tube	Stage 8	Level of future mid-brain.
35 Macrophages	12 s	From endothelium or mesenchyme.	112 Neuroblasts, retinal	4th da	Fundus of retina.
36 Thrombocytes	3-4 da		113 Nictitating membrane	7th da	From semilunar fold of integument within eyelid on side next to beak.
37 Bursa of Fabricius ⁶	5-6 da	Posterodorsal wall of cloaca.			
38 Cecal processes	7th da	Junction of small and large intestine.	114 Notochord (see Head-process)		
39 Canal of Schlemm	8th da	Margin of anterior chamber of eye.	115 Oculomotor nerve	28-30 s	Ventral zone of mid-brain, near median line.
40 Cardinal vein, anterior	12 s	From intersegmental capillary sprouts of the dorsal aorta.	116 Olfactory epithelium	28 s	Ectoderm of head, in front of eyes.
41 Cerebellar fissures	10-11 da	External surface of cerebellum.	117 Olfactory nerve	4-6 da	Olfactory epithelium.
42 Chorion (see Amnion)			118 Oocytes	Shortly after hatching	Ovarian cortex.
43 Chromaffin cells (see Adrenal, medullary component)					
44 Ciliary processes	8th da	From ciliary region of lenticular zone of optic cup.			
45 Circulation of blood					
46 Clavicle	8-9 da				
47 Ossification					

40	Claws	10 da (Stage 36)		118	Oogonia	7-8 da	From germ cells in secondary sexual cords of ovarian cortex.
41	Coelom	1-3 s	Within lateral plate mesoderm.	119	Optic vesicles	Stages 8-9	From lateral wall of fore-brain.
42	Comb	10 da (Stage 36)	Dorsal midline of beak.	120	Oral plate, rupture	30 s	
43	Conjunctival sac	7th da	Within folds of eyelids.	121	Ostium tubae abdominale	5th da	Anterior end of tubal ridge (primordium of oviduct).
44	Coracoid, chondrification	End of 6th da	Near union of coracoid with scapula.	122	Otocyst	12 s	Thickened ectoderm on dorsal surface of head opposite posterior-most neuromeres of hind-brain.
45	Cornea propria	4th da	Beneath the corneal epithelium.	123	Otocyst closure	28-30 s	
46	Cornea, inner epithelium (Bowman's membrane)	100th hr	From mesenchyme on inner face of cornea propria.	124	Ovary, cortex	9-11 da	Proliferation from germinal epithelium.
47	Cornea, Descemet's membrane	13-15 da	Beneath Bowman's membrane.	125	Oviduct	4th da	Thickened peritoneum on dorsolateral surface of anterior end of mesonephros.
48	Costal processes (ribs)	5th da		126	Oviduct, junction with cloaca	7th da	
49	Crop	6th da	Dilation of esophagus at base of neck.	127	Palatine glands	After 11th da	From oral epithelium near choanae.
50	Cushions, endocardial, of atrioventricular canal	3-4 da	Floor and roof of the atrioventricular canal.	128	Pancreas ¹⁵ , dorsal diverticulum	35 s	Dorsal wall of intestine, immediately above posterior liver bud.
51	Dermis differentiation of fibers	Stage 38 (12 da)	Within mesenchyme next to ectoderm.	129	Pancreas ¹⁵ , ventral diverticulum	4 da	From common hepatic diverticulum near its junction with duodenum.
52	Diencephalon delimitation	18-20 s	From primitive fore-brain.	130	Paraphysis	4½ da	Roof of telencephalon, just in front of the velum transversum.
53	Duct of Cuvier (common cardinal vein)	15 s	From capillary plexus between root of anterior cardinal vein and omphalomesenteric vein at level of somite 4.	131	Parasphenoid bone	12th da	Skull.
54	Ductus choledochus	68 hr	From depression of ventral wall of duodenum.	132	Parathyroid	6-8 da	Ventral portion of visceral pouches 3 and 4.
55	Egg-tooth ²	Stage 30 (6½-7 da)	Dorsal tip of beak.	133	Paracephalon	18-20 s	Anterior portion of diencephalon.
56	Embryonic shield	Stage 1	Posterior half of blastoderm.	134	Parietal bone	13th da	Skull, behind squamosal bone.
57	Epimyocardium ⁸	3-5 s	From thickening of splanchnopleure of amnio-cardiac vesicles.	135	Patella	13th da	Anterior face of knee joint.
58	Epiphysis	Stage 17 (30-35 s)	Roof of diencephalon.	136	Pecten	5th da	Growth of lips of optic cup over mesodermal keel of choroid fissure.
59	Epithalamus	97 hr	Dorsolateral wall of diencephalon.	137	Pelvic lymph sac	5 da	Hemangioblasts from intersegmental veins of pelvic region.
60	Esophagus	About 36 s	Gut immediately behind pharynx.	138	Perilymph of ear	6th da	Mesenchyme surrounding otocyst.
61	Esophagus, glands ⁹	16 da	From entodermal epithelial lining of esophagus.	139	Pharynx (foregut)	Stage 6	From entoderm of head fold.
62	Eye pigment	Stage 20		140	Pigment of choroidea of eye	End of 7th da	From neural crest cells which invade at early stage.
63	Eyelids	7th da	Circular fold of integument around the eyeball.	141	Pigment of retina	Middle of 4th da	In situ in outer wall of retina.
64	Facial nerve	3-4 da	From anteroventral portion of acoustico-facialis complex.		Pleuroperitoneal septum (see Mesenteries, accessory)		
65	Femur, ossification	8th da		142	Preganglionic column (visceral motor nucleus)	4½-8 da	From neuroblasts of ventrolateral motor column, which migrate to dorsolateral angle of central canal, spinal cord.
66	Funiculi proocervicales	6th da	From ectoderm connecting 3rd and 4th visceral pouches with cervical sinus.	143	Premandibular head cavities	23 s	Within prechordal mesoderm.
67	Gallbladder	68 hr	Hindmost part of posterior liver bud.	144	Premaxilla (bone)	End of 9th da	Skull.
68	Germ wall	During cleavage (prior to laying)	From marginal periblast.	145	Primitive streak	Stage 2	Posterior edge of pellucid area.
69	Germinal epithelium (primordium of gonad)	38 s	Coelomic epithelium at level of somites 20-27.	146	Proventricular glands	5th da	Evaginations of entoderm of stomach.
70	Gizzard	5th da	Posterior part of stomach.	147	Pterygoid bone	End of 9th da	Skull.
71	Gizzard glands ¹⁰	13-14 da	Lining epithelium of gizzard.	148	Pulmonary artery	35 s	From network of hemangioblasts extending caudally from ventral aorta.
72	Glossopharyngeal ganglion	17 s	From neural crest and epibranchial placode of 2nd visceral furrow.	149	Pulmonary diaphragm, muscles	10th da	
73	Glycogenic body of spinal cord	7½ da	Roof plate of spinal cord at level of spinal nerves 26-29.	150	Pulmonary vein	20 s	From proliferation of hemangioblasts from dorsal wall of sinus venosus at level of lung buds.
74	Harderian gland	8th da	From conjunctival sac at innermost angle of nictitating membrane.	151	Quadrate bone, otic process	End of 9th da	Skull.
75	Head fold	Stage 6	At anterior end of medullary plate.	152	Quadratojugal bone	End of 9th da	Skull.
76	Head-process (notochord)	Stage 5	Anterior edge of Hensen's node.	153	Rathke's pouch ¹⁶	20 s	From ectoderm of roof of stomodeum, immediately anterior to oral plate.
77	Hepatic portal vein, definitive vessel	5th da	From the mesenteric vein in the dorsal mesentery.	154	Renal portal system ¹⁷		Through substance of mesonephros.

/1/ 8th da (180 hr). /2/ 19-21 da (time of hatching). /3/ From time of fusion of component folds, shortly after stage of 31 somites. /4/ With beginning of circulation at stage of 16 somites. /5/ Vestigial. /6/ Shortly prior to hatching. /7/ Stage of 16 somites. /8/ Contractions begin at stage of 9 somites. /9/ 19 da. /10/ 17½ da. /11/ 11-12 da. /12/ 7th da. /13/ Beginning of 4th da. /14/ 11th da. /15/ Islets, 11-12 da; acini, after hatching. /16/ Cellular types differentiate during 10th da. /17/ 5th da.

127. PRENATAL DEVELOPMENT, VARIOUS ORGANS AND TISSUES: CHICK (Concluded)

Time of origin is expressed in three ways, depending on available information: (1) days or hours of incubation, (2) number of pairs of somites, or (3) normal "stages" as described by Hamburger, V., and Hamilton, H. L., J. Morphology, 88:49, 1951. Data adapted from Lillie's "Development of the Chick," Henry Holt & Co., 1952. Footnotes refer to onset of function only.

Organ or Structure	Time of Origin	Site of Origin	Organ or Structure	Time of Origin	Site of Origin
155 Rete cords of gonad	5th da	In stroma between genital primordium and mesonephros.	181 Thymus	6-8 da	From dorsal part of visceral pouches 3, 4, and possibly 5.
156 Sacculus	6-7 da	Protuberance on median surface of uppermost part of the pars inferior of the otocyst.	182 Thyroid ¹⁸	12 s	Thickened epithelium of median floor of pharynx between levels of visceral arches II and III.
157 Scales of leg	Stage 37 (11 da)	Anterior surfaces of lower leg and toes.	183 Toe	Stage 25	Toe plate of leg bud.
158 Scapula	4-5 da	Base of wing bud.	184 Trachea	4 da	Hinder portion of laryngotracheal groove.
159 Scleral papillae of eye	Stage 30 (7th da)	On conjunctiva surrounding iris, at some distance peripheral to its margin.	185 Trigeminus, neural crest component	13-14 s	Neural crest of level of metencephalon.
160 Sclerotic cartilage	8 da	In sclerotic (outer) coat of eye.	186 Trigeminus, component from epibranchial placode	25-27 s	From ectodermal placode in front of and above first visceral cleft.
161 Semicircular canals of inner ear	5th da onward to 12th da	From pars superior of otocyst.	187 Trochlear nerve	End of 3rd da	Dorsal surface of brain in region of isthmus.
162 Septal gland of nose	8th da	Solid cord of cells from inner wall of vestibulum, opposite base of the vestibular turbinal.	188 Trunk flexure	Stage 14	Behind level of somites 7-9.
163 Septum aortico-pulmonale	5th-6th da	Within truncus and bulbus arteriosus.	189 Tuberculum impar of tongue	4th da	Slight rounded swelling between lower ends of first and second visceral arches.
164 Shell of egg	4½-24 hr after ovulation	Uterus.	190 Turbinals, nasal Middle ¹⁹	4-8 da	From folds of lateral wall of nasal cavity.
165 Shell membrane of egg	3½-4½ hr after ovulation	Isthmus of oviduct.	191	Beginning of 5th da	From ventral part of lateral nasal wall.
166 Spermatogonia	13th da onward	From primordial germ cells within sexual cords of testis.	192 Superior Vestibular ¹⁹	5-6 da	Immediately above the middle turbinal.
167 Spinal nerves, motor component	3rd da	From medullary neuroblasts of ventral horn, spinal cord.	193 Umbilical vein	6-8 da	From capillary plexus in the somatopleure extending back from duct of Cuvier.
168 Spleen	2nd half, 4th da	Proliferation of peritoneum of left side of dorsal mesentery, just above the dorsal pancreas.	194	3-4 da	Membranous ossifications along sternal ends of ribs (?).
169 Spur	Stage 36	Medial surface of leg, just proximal to base of first toe.	195 Uncinate processes	Da before hatching ²⁰	Broad diverticulum of mesonephric duct at the convexity of its terminal bend to the cloaca.
170 Squamosal bone	End of 9th da	Skull.	196 Ureter ¹⁴	End of 4th da	From a pair of ectodermal invaginations at the dorsal midline of the base of the uropygium.
171 Stapes	7-8 da	From mesenchyme adjacent to the bottom of the external auditory meatus.	197 Uropygial gland ²¹	10th da	Posterior end of left oviduct.
172 Stomodeum	12 s	From expansion of embryonic parts surrounding the oral plate.	198 Uterus (shell-gland) ²¹	12th da	Indistinct aggregation of neural crest immediately in front of level of duct of Cuvier.
173 Subcardinal vein	70 hr	From series of venous islands on median surface of mesonephros.	199 Vagus nerve, neural crest component	20 s	Initiated in blood islands at posterior margin of area opaca.
174 Subclavian artery	4th da	From the segmental artery of the 18th intersomitic space.	200 Vascular system	3-5 s and onward in later stages	Indentation in roof of fore-brain.
175 Subintestinal vein	3rd da	From a plexus of capillaries around the gut.	201 Velum transversum	18-20 s	Within membranous parts of vertebrae.
176 Sympathetic nervous system	End of 3rd or beginning of 4th da	Aggregation of neural crest cells at dorso-lateral angle of dorsal aorta.	202 Vertebrae, chondrification	7-8 da	From the first 5 or 6 segmental arteries, and the plexus they form around the secondary sympathetic ganglia.
177 Synencephalon	18-20 s	Hindmost third of the diencephalon.	203 Vertebral artery	6-7 da	In pharyngeal region.
178 Tail bud	20-21 s	From primitive knot and remnant of primitive streak consolidated with it.	204 Visceral cleft 1	26 s	In pharyngeal region.
179 Teeth (vestige of dental ridge) ⁵	6 da	Thickened ridge of ectoderm just inside margin of jaw.	205 Visceral cleft 2	35 s	In pharyngeal region.
180 Thoracic duct of lymphatic system	6-7 da	From intramesenchymal spaces along ventro-lateral side of dorsal aorta.	206 Visceral cleft 3	40 s	In pharyngeal region.
			207 Visceral pouch 4, contact with ectoderm	35 s	Branchial region. No cleft develops.
			208 Wattles	Stage 37	Throat.
			209 Wing bud	50-60 hr (Stage 16)	Somatopleure lateral to somites 14-20.
			210 Wing feathers	7 1/4 da	Along outer margin of wing.

/5/ Vestigial. /14/ 11th da. /18/ 10th da. /19/ Non-sensory. /20/ Calcification starts at least one day prior to hatching. /21/ After hatching.

128. PRENATAL DEVELOPMENT, VARIOUS ORGANS AND TISSUES: PIG

Organ, Tissue or Characterization	Stage of Appearance	Embryo Size ¹ mm	Age ² da	Organ, Tissue or Characterization	Stage of Appearance	Embryo Size ¹ mm	Age ² da
1 One cell	1	0.11-0.14		27 Caudal somites 47-49; thymus	27	11	21-22
2 Two cells	2		25-41 hr	28 Caudal somites 50-52 (end of somite formation); cervical sinus closing; handplate; pulmonary, subclavian, basilar and vertebral arteries; Jacobson's organ; milk line; Mullerian ducts; parathyroids; neurohypophysis; olfactory lobe and nerve; vitreous body	28	11.6-15	22
3 Four cells	3		25 hr	29 Cervical sinus closed; lateral palatine processes; pentadactyle rudiments; semicircular canals; cochlea; pia mater and arachnoid layer; sympathetic ganglia and ramus anastomoticus; chondrification of vertebrae; appearance of sternum; cecum; milk hillocks; calyces	29	16.4-18.6	22
4 Eight to twelve cells	4		3	30 Median (premaxillary) palatine processes; sex differentiation; eyelids and plica semilunaris; testis differentiated; glomeruli and convoluted tubules in metanephros; appearance of presternum; brachiocephalic and left common carotid arteries; epiphysis; hair follicles; mammary gland primordia; dental lamina; enamel organs; coils of small intestine; anus open	30	19.4-24	28
5 Sixteen cells (morula)	5	3.5	3.5	31 Facial clefts closing; palate developing; heart myoblasts become spindle-shaped	31	25.0	30
6 Blastocyst	6	4.75	5-7	32 Phalanges (3rd and 4th most prominent); fusion of palatine processes; mandible ossifies; elongation of nuclei in longitudinal muscle layer of esophagus and stomach	32	26.6-30	32.5
7 Late blastocyst (still free in uterus)	7		7-8	33 Facial clefts closed; palate completed; femur ossifies; coils of large intestine; humerus ossifies; ribs start to ossify; adrenal medulla; nasal chamber and nasal septum complete; cerebellum; muscle bundles	33	30-38	34.5
8 Bilaminar disc (beginning elongation)	8	0.49-1.36 ³	8-9	34 Growth of eyelids; gut withdrawn from umbilical cord; muscularis mucosae; bodies and arches of vertebrae start to ossify	34	40.0	36.5
9 Proliferation of mesoderm	9	2.5-3.0 ³	8-9	35 Sealed eyelids	35	44.5	39
10 Primitive streak beginning	10		10	36 Penis raphé	35	60.0	44
11 Medium primitive streak	11		10	37 Prepuce, scrotum in male; labia majora, clitoris in female	35	70.0	46
12 Completed primitive streak; notochord	12	10-65 ³	11-12	38 Neuroglia present	35	75.0	48
13 Presomite neurula; neural plate and groove; hindgut	13		13	39 Odontoid process ossifies	35	76.0	48
14 Pericardial cavity; endocardium; epimyocardium; anlagen of blood vessels; foregut; preoral gut; oral plate; allantois; occipital somites 1-4 ⁴	14	2.5-3.0	14-15	40 Intercalated discs appear			
15 Cervical somites 5-12; visceral pouches 1-2; pharynx; mesonephros; neural tube; fusion of neural crest primordia; auditory placode; optic vesicle; fusion of paired cardiac tubes; blood in yolk sac, heart and vessels; ventral aorta	15	3.2-5.2	15-16	41 Seminal vesicles, prostate, Cowper's glands in male; oviducts, uteri and vagina in female	35	85.0	51
16 Thoracic somites 13-20; spiral torsion; truncus and bulbus arteriosus; ventricle; atrium; sinus venosus; glomeruli in mesonephros; dorsal aortae; first pair aortic arches; 3rd and 4th visceral pouches; liver diverticula; prosencephalon; mesencephalon; rhombencephalon; auditory pit	16	4.0-6.5	15-17	42 Intercalated discs extend across cardiac muscle fibers	35	89.0	52
17 Thoracic somites 21-24; telencephalon; diencephalon; metencephalon; myelencephalon; closure of anterior neuropore; longitudinal neural artery; lateral cardinal vein	17	4.9-6.5	17	43 Tonsil	35	90.0	52
18 Thoracic somites 25-26; head and tail meet; anterior limb bud; 2nd aortic arch; endocardial cushions; esophagus; stomach; post-cloacal gut; proctodaeum; anal plate; intestine; auditory vesicle; thyroid; hypophysis	18	3.8-4.5 ⁵	16.5-18	44 Corpora quadrigemina	35	100.0	54.5
19 Lumbar somites 27-29; hind limb bud; pancreas; lung buds; 3rd aortic arch; Gasserian and acoustico-facialis ganglia; interventricular septum	19	3.6-4.6	16.5-17.5	45 Nymphae (labia minora)	35	113.0	58.5
20 Lumbar somites 30-31; spiraling completed; 4th aortic arch; mesial cardinal vein; venous valves; oral plate ruptures; gallbladder; trachea	20	4.5-7.0	17.5	46 Ameloblasts and odontoblasts	35	120.0	61
21 Lumbar somites 32-33; uncoiling; mandibular and maxillary processes; elongation of nuclei of mesenchyme cells in region of circular muscle layer of esophagus at level of laryngotracheal groove	21	5.0-5.2	17.5	47 Sternebrae start to ossify	35	125.0	62
22 Sacral somites 34-35; cranial ganglia IX and X; cranial nerves 3-12; optic cup and lens; 6th aortic arch; epiglottis; notochordal sheath; tongue primordia	22	5.8-8.0	19	48 Testis descending	35	128.0	62.5
23 Sacral somites 36-37; metanephric duct; foramen II in septum I	23	6.4	20	49 Petrous portion of temporal last to ossify, dentine and enamel	35	130.0	63
24 Caudal somites 38-40	24		20	50 Sulci and gyri in cerebrum	35	200.0	92
25 Caudal somites 41-43; olfactory pits; lateral and median nasal processes; septum II; external carotid; adrenal cortex; myoblasts elongate; dermomyotome differentiates	25	8.0-8.6	20	51 Testis entering inguinal canal	35	210.0	95
26 Caudal somites 44-46; beginning umbilical hernia; pelvis; bronchi branching; myofibrillae in myoblasts of esophagus; ependymal mantle and marginal layers of neural tube; neuroblasts; retinal differentiation; cerebral hemispheres; sacculus; utriculus; bulbus dividing into aortic and pulmonary trunks; inferior vena cava; spleen; anlagen of external genitalia	26	9.0-10.0	20-21	52 Eyelids separate	36	250-300	98-140
				53 Birth			

/1/ Greatest length, neck length (spine length) or crown-rump length of embryo. /2/ Unless otherwise noted. /3/ Extra-embryonic length. /4/ 1st somite not delimited anteriorly. /5/ Apparent decrease in size may be attributed to torsion of embryo.

129. PRENATAL DEVELOPMENT, VARIOUS ORGANS AND TISSUES: FROG

Data for embryo stages adapted from Shumway, W., Anat. Rec., 78:139-144, 1940. Larval stage data adapted from Taylor, A. C., and Kollos, J. J., Anat. Rec. 94:7-23, 1946. Values are principally for *Rana pipiens*, but may vary widely with different geographic strains and culture conditions.

Organ, Tissue or Characteristic	Stage	Size mm	Age ¹	Organ, Tissue or Characteristic	Stage	Size mm	Age ¹
Embryo				Larva			
1 Unfertilized egg	1	1.5-2	0	26 Feeding begins; rudiments of adrenal medulla and of hind limb appear	I	13	3
2 Fertilized egg; gray crescent	2	1.5-2	1	27 Lagenia; neural lobe of hypophysis	II	17	6
3 Two cells	3		3.5	28 Limb bud of equal length and diameter; lateral motor column	III	23	11
4 Four cells	4		4.5	29 Ovarial sac; cartilage in synotic tectum	IV	33	19
5 Eight cells	5		5.7	30 Limb bud twice as long as it is broad; bent ventrad distally	V	39	23
6 Sixteen cells	6		6.5	31 Flattened paddle at distal end of limb bud; scapular cartilage; ovary-testis distinguishable	VI	43	26
7 Thirty-two cells	7		7.5	32 Foot paddle indented between toes 4 and 5	VII	50	31
8 Middle blastula	8		16	33 Urinary bladder rudiment; measurable thyroid hormone output	VIII	53	34
9 Late blastula	9		21	34 Separation of fat body from gonad; spontaneous limb twitches	IX	56	36
10 Early gastrula; dorsal lip stage	10		26	35 All toes marked by indentation of the foot margin between them; rudiments of fungiform papillae of tongue	X	58	40
11 Middle gastrula; blastopore C- or U-shaped	11		34	36 Margin of fifth toe web directed toward toe 2	XI	61	43
12 Late gastrula; yolk plug; primitive gut	12		42	37 Margin of fifth toe web directed toward toe 1	XII	64	47
13 Early neurula; medullary plate defined	13		50	38 Margin of fifth toe web directed toward the prehallux	XIII	67	52
14 Mid-neurula; well-defined neural folds approaching each other; oral plate; anal pit; postanal gut	14		62	39 Rudiments of Harderian glands, and of skin glands	XIV	70	58
15 Late neurula; neural folds touch each other over most of their length; neurenteric canal; embryo rotates in jelly	15		67	40 First toe pads; hind limbs take part in swimming	XV	72	62
16 Neural tube; ectoderm fused over it; oral sucker	16	3	72	41 Nictitating membrane a low fold anterior to eyeball	XVI	73	64
17 Tail bud; nasal pit; dorsal aorta	17	3.5	84	42 Some skin glands patent; peritoneal thickening presages oviduct	XVII	73	67
18 Muscular response to stimulation of myotome; lens placode	18	4	96	43 Cloacal tail piece resorbed; corneal reflex	XVIII	74 ²	70
19 Heart beats; pronephros functional; Rohon-Beard cells; thyroid evagination	19	5	118	44 Tail regression begins; skin windows form	XIX	73	72
20 Embryo hatched; gill circulation; lens vesicle	20	6	140	45 Skin windows perforate; forelimbs emerge; oral beaks lost	XX	70	74
21 Mouth open; free swimming; cornea becoming transparent; olfactory nerve; two rudiments of ventral pancreas; lung rudiments	21	7	162	46 Upper lid forms; first molt	XXI	63	76
22 Circulation in tail fin; cartilaginous trabeculae; two gill slits are perforate; trabeculae carnae	22	8	192	47 Conjunctival sac complete; lateral lines regressing	XXII	44	79
23 Opercular folds and labial teeth appear; spontaneous respiratory activity of mouth begins; basal plate	23	8-9	216	48 Labial fringes completely lost; vasa efferentia	XXIII	33	81
24 Operculum closed on right side; adrenal cortex rudiment; respiratory rhythm begins	24	9-10	240	49 Tympanic membrane outlined; tail stub of 1-2 mm	XXIV	26	84
25 Operculum closed except for spiracle; rods and cones; germinal ridge; sucker regressed; rudiments of mesonephric tubules	25	10-11	284	50 Tail stub fully resorbed; oviduct extends nearly to cloaca	XXV	25 ³	88
				51 Fully metamorphosed; gonads immature; urostyle	Junvenile	25-70	90-
				52 Sexually mature	Adult	60-110	1-3 yr

/1/ Age is expressed in hours (at 18°C) for embryo stages 1-25, in days (at 20°C) for succeeding stages. Ages for embryo stages 2 through 20 in hours at 20°C are: 0.5, 2.3, 3.2, 4.0, 4.8, 5.6, 7.0, 17.0, 22, 28, 30, 38, 43, 49, 52, 61, 76, 88 and 96, respectively. /2/ Maximum size highly variable. Tadpoles over 100 mm length reported. /3/ Size at end of metamorphosis variable. Range 16-30 mm.

130. SUMMARY, DEVELOPMENT CHARACTERISTICS: MAMMALS AND BIRDS

Hours and days are counted from the time of fertilization. In birds one day was added to observed incubation times; in mammals observed mating ages were reduced by the estimated number of hours necessary for the establishment of contact between egg and sperm (opossum 8, rabbit 14, hamster 8, rat 9, pig 8, sheep 6). In the monkey the ovulation age (Lewis-Hartman) was reduced by 2 hours. Values adapted from E. Witschi's "Development of Vertebrates," W. B. Saunders Co., 1956.

Stage	Hawk	Chick	Sparrow	Opossum	Rabbit	Hamster	Rat	Swine	Sheep	Rhesus Monkey	Man
1 2 cells, hr		3		40	8	16	24	30	30	24	38
2 4 cells, hr		3 1/4		56	11	40	50	34	34	36	48
3 Implantation begins, da				6	7	4 1/2	6	7	10	9	6 1/2
4 12 Primitive streak, da	1 1/2-2	1 1/2-2	7-7 1/2	6 1/2-7	6 1/2-7	6 1/2-7	8 1/2-9	11-12	13	18-20	17-21
5 16 13-20 somite embryo, da	4 1/2	2 1/2	2 1/2	9	9	8	10 1/2	17	25	25	27
6 17 Tailbud forms, da		3 1/4	3 1/4	9 1/2	9 1/2	8 1/2	11 1/2	17	18	26	29
7 25 End of embryonic period, da	9	5	5	10	10	9	13	20	21	28	36
8 33/1 End of metamorphosis, da	13	8	7 1/2	12	14	13 1/2	16	24	32	40	60
9 Sex differentiation, da	12	6 1/2	6 1/2	15	13 1/2	13	13 1/2	21	28	36	45
10 35 Eyelids closed, da	23	13	11	12 1/4	19		17	32	42	48	70
11 36 Eyelids open, da		20	19				38		84		180
Hatching or birth											
12 Age, da	35	21	13	12 1/2	32	22	112	150	164	267	
13 Stage	35/36	36	35	35	35+	35	35	36	36	36	36
14 Weight, absolute, kg	0.012	.034	0.0017	0.13 ¹	0.057	0.0022	0.0045	2.5	5	450	3.2
15 Relative to mother, %		3	6	0.01	3	2.3	2.25	2.5	8	7.5	5.5

/1/ Grams.

131. GROWTH: VERTEBRATES

Cattle: ¹		Ayrshire ¹		Brown Swiss ¹		Guernsey ¹		Holstein ^{1,2}		Jersey ^{1,2}	
Age and Sex		kg	lb	kg	lb	kg	lb	kg	lb	kg	lb
1 Birth ♂		33-40	73-89	43-50	95-110	29-41	65-90	42-47	92-104	22-29	49-64
2 1 wk ♂		34-43	76-94	45-53	100-117	34-41	75-90	46-49	101-109	25-29	56-65
3 2 wk ♂		39-49	86-108	53-59	116-130	41-47	90-103	48-54	106-120	28-35	62-77
4 3 wk ♂		42-57	92-127	60-68	133-150	45-51	99-113	53-65	116-144	33-38	73-83
5 4 wk ♂		52-65	114-143	68-83	151-183	49-57	108-125	57-73	125-162	36-43	79-96
6 5 wk ♂		58-77	128-169	78-92	173-204	59-65	130-143	64-79	141-174	41-48	90-106
7 6 wk ♂		68-88	150-195	86-99	190-218	66-70	145-155	66-86	145-190	49-56	107-123
8 7 wk ♂		75-97	165-213	96-106	211-234	74-76	164-168	75-96	165-213	57-64	126-142
9 8 wk ♂		82-102	180-225	102-117	227-259	84-86	186-190	92-107	202-236	63-77	140-169
10 3 mo ♀								96	211	64	141
11 6 mo ♀								176	389	127	281
12 9 mo ♀								254	561	193	426
13 1 yr ♀								315	697	233	514
14 2.5 yr ♀								525	1158	400	883
15 6-7 yr ♀								649	1433	477	1052

Dog:		Basenjis		Beagle		Cocker spaniel		German shepherd ³	
Age and Sex		kg	lb	kg	lb	kg	lb	kg	lb
16 Birth ♂		0.23-0.34	0.50-0.75	0.40	0.88	0.20-0.30	0.44-0.66	0.39-0.52	0.87-1.14
17 1 wk ♀		0.26-0.30	0.57-0.66	0.30	0.66	0.20-0.31	0.44-0.68		
18 2 wk ♀		0.34-0.48	0.75-1.06	0.69	1.52	0.32-0.54	0.71-1.19	0.71-0.92	1.56-2.02
19 3 wk ♀		0.34-0.51	0.75-1.12	0.56	1.23	0.32-0.57	0.71-1.26		
20 4 wk ♀		0.52-0.68	1.15-1.50	1.01	2.23	0.50-0.77	1.10-1.70	1.31-1.56	2.90-3.45
21 5 wk ♀		0.52-0.71	1.15-1.56	0.80	1.76	0.50-0.77	1.10-1.70		
22 6 wk ♀		0.80-1.11	1.76-2.45	1.61	3.55	0.82-1.33	1.81-2.93	2.86-3.04	6.32-6.70
23 7 wk ♀		0.70-1.14	1.54-2.51	1.26	2.78	0.86-1.25	1.90-2.76		
24 8 wk ♀		1.22-1.66	2.69-3.66	2.48	5.47	1.46-2.30	3.22-5.07	4.45-5.04	9.82-11.13
25 9 wk ♀		1.06-1.64	2.34-3.61	1.79	3.95	1.54-2.14	3.39-4.72		
26 10 wk ♀		1.93-2.64	4.25-5.82	3.54	7.80	2.66-3.69	5.86-8.13	15.4-35.2	7.0-16.0
27 11 wk ♀		1.76-2.92	3.88-6.44	2.53	5.58	2.30-3.26	5.07-7.19	17.6-39.6	8.0-18.0
28 12 wk ♀		2.72-3.90	5.99-8.60	4.59	10.12	3.52-4.62	7.76-10.18	20.9-47.5	9.5-22.5
29 13 wk ♀		2.52-3.86	5.55-8.51	3.26	7.19	3.02-4.24	6.66-9.34	20.9-53.9	9.5-24.5
30 14 wk ♀		3.40-4.96	7.49-10.93	5.81	12.81	4.54-6.27	10.01-13.82	23.1-64.9	10.5-29.5
31 15 wk ♀		3.52-4.88	7.76-10.76	4.22	9.31	3.98-5.36	8.77-11.81	34.1-61.6	15.5-28.0
32 16 wk ♀		4.64-6.41	10.23-14.13	6.98	15.38	5.39-7.63	11.88-16.82	26.4-81.4	12.0-37.0
33 17 wk ♀		4.24-5.96	9.34-13.14	4.84	10.67	4.76-6.54	10.49-14.41	36.3-69.3	16.5-31.5
34 18 wk ♀		5.52-7.36	12.17-16.22	7.89	17.39	6.42-8.96	14.15-19.75	29.7-94.6	13.5-43.0
35 19 wk ♀		5.07-6.88	11.17-15.16	5.45	12.01	5.32-7.28	11.73-16.05	36.3-83.6	16.5-38.0

Goat:		Saanen, ♂		Saanen, ♀		Toggenburg, ♂		Toggenburg, ♀	
Age		kg	lb	kg	lb	kg	lb	kg	lb
36 Birth		3.6(3.0-4.2)	7.9(6.6-9.3)	3.1(2.4-3.9)	6.9(5.3-8.6)	3.5(2.9-4.1)	7.7(6.4-9.0)	3.1(2.5-3.6)	6.8(5.6-8.0)
37 1 mo		7.2(6.0-8.4)	15.8(13.1-18.5)	6.7(5.4-8.0)	14.8(11.9-17.7)	6.8(5.6-7.9)	14.9(12.4-17.4)	6.4(5.4-7.3)	14.0(11.9-16.1)
38 2 mo		11.3(9.4-13.2)	25(21-29)	11.0(9.2-13.0)	24(20-28)	11.2(9.6-12.8)	25(21-28)	10.2(8.8-11.6)	23(20-26)
39 3 mo		15.0(12.1-17.8)	33(27-39)	14.6(11.8-17.3)	32(26-38)	15.0(12.5-17.4)	33(28-38)	13.7(12.0-15.5)	30(26-34)
40 6 mo		25(20-30)	54(43-65)	25(20-29)	54(44-64)	23(20-27)	51(44-59)	21(18-24)	46(39-53)
41 9 mo		31(26-35)	67(57-78)	30(24-35)	66(54-78)	27(23-32)	60(51-69)	25(22-29)	56(48-64)
42 1 yr		41(34-47)	90(76-104)	35(28-42)	78(63-93)	35(30-39)	77(67-87)	29(25-33)	64(55-73)
43 2 yr		58(44-72)	128(97-160)	54(44-64)	118(97-140)	48(39-57)	106(87-125)	45(37-53)	99(81-117)
44 3 yr		68(51-85)	149(112-187)	58(46-71)	129(101-157)	58(49-68)	128(108-149)	52(41-62)	114(91-136)
45 4 yr		82	180	60(49-72)	133(107-159)	71(62-80)	156(136-177)	52(43-61)	114(94-133)
46 5 yr		77	169	70(54-86)	155(119-190)	67(49-84)	147(108-185)	54(47-61)	120(104-135)

Guinea Pig:		Cavia cutleri		Race B		Inbred Line		Random Breed	
Age		g	oz	g	oz	g	oz	g	oz
47 Birth		50	1.8	50	1.8	80	2.8	80	2.8
48 10		70	2.5	70	2.5	90	3.2	90	3.2
49 20		110	3.9	110	3.9	130	4.6	130	4.6
50 40		160	5.6	160	5.6	200	7.0	200	7.0
51 60		210	7.4	200	7.0	280	9.9	250	8.8
52 80		260	9.2	230	8.1	360	12.7	330	11.6
53 100		300	10.6	260	9.2	440	15.5	400	14.1
54 120		330	11.6	280	9.9	500	17.6	450	15.9
55 160		360	12.7	300	10.6	590	20.8	530	18.7
56 200		380	13.4	320	11.3	660	23.3	610	21.5
57 240		390	13.8	340	12.0	710	25.0	670	23.6
58 280		400	14.1	360	12.7	750	26.4	700	24.7
59 320		410	14.5	380	13.4	790	27.8	720	25.4
60 360		420	14.8	400	14.1	800	28.2	740	26.1
61 400		420	14.8	400	14.1	800	28.2	740	26.1

Monkey:		Macaque		Marmoset, squirrel		Black-howler		Spider		White-faced	
Age and Sex		kg	lb	kg	lb	kg	lb	kg	lb	kg	lb
62 Birth		0.49(0.39-0.67)	1.08(0.85-1.47)			1.59	3.5	0.91	2	0.02	0.5
63 10		0.47(0.33-0.64)	1.02(0.72-1.41)			(0.91-1.13)	(2-2.5)	(0.68-1.13)	(1.5-2.5)	(0.45-0.67)	(1-1.5)
64 Juvenile		1.45(1.07-1.88)	3.19(2.34-4.14)			2.72	6	(2.27-2.72)	(5-6)	1.81	4
65 1 yr		1.42(0.89-1.80)	3.10(1.96-3.96)			2.27	5	1.81	4	(1.36-1.59)	(3-3.5)
66 "Young"-		2.20(1.48-2.98)	4.83(3.25-6.56)	0.453	1			(3.62-5.44)	(8-12)	(2.72-3.17)	(6-7)
67 adult		2.19(1.45-2.68)	4.81(3.19-5.90)			4.08(3.62-6.34)	(8-14)	(4.08-5.89)	(9-13)	(1.59-2.27)	(3.5-5.5)
68 "Old"-		11.0(8.8-12.1)	24.1(19.4-26.7)	(0.57-0.79)	(1.25-1.75)	(6.34-8.15)	(14-18)	(6.8-8.6)	(15-19)	3.9(3.4-5.4)	8.5(7.5-12)
69 adult		8.01(6.31-12.2)	17.6(13.9-26.8)	0.68(0.45-0.91)	1.5(1-2)	(4.98-7.47)	(11-16.5)	(6.34-8.61)	(14-19)		

/1/ Data for first 8 weeks obtained by one investigator under conditions of ad libitum feeding of milk alone. /2/ Data for 3 months to 7 years obtained by another investigator under practical feeding conditions, hence show slower gains. /3/ Values in Lines 16-25 and 26-35 are from different sources.

131. GROWTH: VERTEBRATES (Continued)

Mouse:		Black, piebald, ♂		Black, piebald, ♀		White, ♂							
Age		g	oz	g	oz	g	oz						
70	Birth	1.4(1.1-1.7)	0.05(0.04-0.06)	1.4(1.1-1.7)	0.05(0.04-0.06)								
71	2 da	6.1(4.4-7.7)	0.22(0.16-0.27)	6.1(4.5-7.7)	0.21(0.16-0.27)								
72	3 wk	8.0(5.6-10.4)	0.28(0.20-0.37)	8.3(6.3-10.4)	0.29(0.22-0.37)	8.2(7.3-8.9)	0.29(0.26-0.32)						
73	4 wk	12.3(9.8-14.7)	0.43(0.35-0.52)	12.1(9.7-14.5)	0.43(0.34-0.51)	12.4(11.6-13.3)	0.44(0.41-0.47)						
74	6 wk	19.1(15.3-22.9)	0.67(0.54-0.81)	18.3(16.0-20.6)	0.65(0.57-0.73)	19.6(18.7-20.5)	0.69(0.66-0.72)						
75	8 wk	22.6(18.8-26.4)	0.80(0.66-0.93)	19.7(16.5-22.8)	0.70(0.58-0.80)	22.2(20.9-23.5)	0.78(0.74-0.83)						
76	12 wk	25.9(22.2-29.5)	0.91(0.79-1.04)	23.6(19.0-28.2)	0.83(0.67-0.99)	25.3(24.2-26.4)	0.89(0.85-0.93)						
77	16 wk	28.6(21.1-36.0)	1.01(0.74-1.27)	26.5(20.1-33.0)	0.94(0.71-1.16)	27.2(25.7-28.7)	0.96(0.91-1.01)						
78	20 wk	30.0(21.8-38.3)	1.06(0.77-1.35)	29.0(21.8-36.1)	1.02(0.77-1.27)	27.8(26.4-29.2)	0.98(0.93-1.03)						
79	24 wk	33.1(25.7-40.5)	1.17(0.91-1.43)	32.3(25.5-39.1)	1.14(0.90-1.38)	27.6(26.3-28.8)	0.97(0.93-1.02)						
80	28 wk					28.0(26.3-29.7)	0.99(0.93-1.05)						
81	32 wk					29.4(28.2-30.5)	1.04(0.99-1.08)						
Rat:		Sherman, albino, small, ♂		Sherman, albino, small, ♀		Sherman, albino, large, ♂		Sherman, albino, large, ♀					
Age		g	oz	g	oz	g	oz	g	oz				
82	Birth	5.5(4.9-6.1)	0.19(0.17-0.22)	5.5(4.8-6.2)	0.19(0.17-0.22)	6.1(4.9-7.7)	0.21(0.17-0.27)	5.8(4.9-6.6)	0.20(0.17-0.23)				
83	1 wk	13.4(10-17)	0.47(0.35-0.60)	13.1(10.5-16)	0.46(0.37-0.56)	17.5(12.5-23)	0.6(0.4-0.8)	16.2(13-19)	0.57(0.45-0.67)				
84	2 wk	25(21-30)	0.88(0.74-1.06)	25(20-30)	0.88(0.71-1.06)	37(29-45)	1.3(1.0-1.6)	34(28-40)	1.2(1.0-1.4)				
85	4 wk	61(51-71)	2.2(1.8-2.5)	56(48-63)	2.0(1.7-2.2)	93(78-108)	3.3(2.8-3.8)	80(68-91)	2.8(2.4-3.2)				
86	6 wk	121(106-136)	4.3(3.7-4.8)	100(89-111)	3.5(3.1-3.9)	188(157-218)	6.6(5.6-7.7)	147(128-166)	5.2(4.5-5.9)				
87	8 wk	177(149-205)	6.2(5.3-7.2)	130(122-137)	4.6(4.3-4.8)	274(231-317)	9.7(8.1-11.2)	196(169-222)	6.9(6.0-7.8)				
88	10 wk	222(191-254)	7.8(6.7-9.0)	154(145-163)	5.4(5.1-5.8)	339(291-386)	12.0(10.3-13.6)	227(199-256)	8.0(7.0-9.0)				
89	12 wk	252(213-291)	8.9(7.5-10.3)	169(159-179)	6.0(5.6-6.3)	393(328-458)	13.9(11.6-16.2)	251(232-280)	8.9(8.2-9.9)				
90	15 wk	285(241-329)	10.0(8.5-11.6)	185(165-205)	6.5(5.8-7.2)	440(379-501)	15.5(13.4-17.7)	274(238-310)	9.6(8.4-10.9)				
91	20 wk	326(278-373)	11.5(9.8-13.2)	202(178-225)	7.1(6.3-7.9)	490(423-556)	17.3(14.9-19.6)	303(270-335)	10.7(9.5-11.8)				
92	30 wk	376(335-417)	13.3(11.8-14.7)	230(205-255)	8.1(7.2-9.0)			335(298-373)	11.8(10.5-13.2)				
93	40 wk			240(215-265)	8.5(7.6-9.3)			358(311-404)	12.6(11.0-14.3)				
Rat:		Wistar, albino, ♂		Wistar, albino, ♀		Wild Norway, ♂		Wild Norway, ♀					
Age		g	oz	g	oz	g	oz	g	oz				
94	Birth	5.6(4.5-6.7)	0.2(0.16-0.23)	5.3(4.5-6.1)	0.18(0.16-0.22)								
95	3 wk	43(38-49)	1.5(1.3-1.7)	41(34-48)	1.4(1.2-1.7)								
96	4 wk	52	1.8	55	1.9								
97	6 wk	110	3.9	97	3.4	85(67-112)	3.0(2.4-3.9)	104(79-142)	3.7(2.8-5.0)				
98	8 wk	170	6.0	128	4.5	170(127-218)	6.0(4.5-7.7)	152(120-200)	5.4(4.2-7.1)				
99	10 wk	200	7.1	147	5.2								
100	12 wk	225(182-286)	7.9(6.4-10.1)	165(143-187)	5.8(5.0-6.6)	237(176-299)	8.4(6.2-10.6)	194(149-249)	6.8(5.2-8.8)				
101	15 wk	251	8.8	180	6.3	289(217-361)	10.2(7.7-12.7)	230(178-291)	8.1(6.3-10.3)				
102	17 wk					330(251-408)	11.6(8.9-14.4)	260(203-327)	9.2(7.2-11.5)				
103	20 wk	280	9.9	200	7.1								
104	23 wk					388(302-472)	13.7(10.7-16.7)	311(245-383)	11.0(8.6-13.5)				
105	28 wk					424(335-509)	15.0(11.8-18.0)	348(276-423)	12.3(9.7-14.9)				
106	35 wk					446(358-531)	15.7(12.6-18.7)	376(300-452)	13.3(10.6-15.9)				
107	40 wk	342	12.1	245	8.6	460(374-545)	16.2(13.2-19.2)	397(319-473)	14.0(11.3-16.7)				
108	45 wk					468(385-551)	16.5(13.6-19.4)	413(333-488)	14.6(11.8-17.2)				
109	50 wk					474(392-556)	16.7(13.8-19.6)	424(344-497)	15.0(12.1-17.5)				
110	52 wk	364(263-465)	12.8(9.3-16.4)	243(196-290)	8.6(6.9-10.2)								
111	57 wk					477(397-558)	16.8(14.0-19.7)	433(352-507)	15.3(12.4-17.9)				
Swine:		Berkshire		Duroc-Jersey		Yorkshire							
Age		kg	lb	kg	lb	kg	lb						
112	Birth	1.84(1.34-2.17)	4.06(2.95-4.78)	2.74(2.73-2.76)	6.04(6.02-6.08)								
113	1 wk	2.58(2.17-3.10)	5.69(4.78-6.83)	3.30(2.96-3.64)	7.27(6.52-8.02)								
114	2 wk	4.32(3.47-4.91)	9.52(7.65-10.82)	5.25(4.75-5.74)	11.57(10.47-12.65)								
115	3 wk	7.02(5.78-8.14)	15.47(12.74-17.94)	7.43(6.84-8.03)	16.38(15.07-17.70)								
116	4 wk	9.85(8.43-12.60)	21.70(18.58-27.8)	8.84(8.55-9.12)	19.48(18.84-20.10)								
117	5 wk	14.02(12.30-17.00)	30.9(27.1-37.5)	13.13(12.80-13.45)	28.9(28.2-29.6)								
118	6 wk	18.31(16.14-21.36)	40.4(35.6-47.1)	16.96(16.50-17.45)	37.4(36.4-38.5)								
119	7 wk	23.16(21.02-27.04)	51.0(46.3-59.6)	20.94(20.43-21.45)	46.2(45.0-47.3)								
120	8 wk	27.45(24.32-31.36)	60.5(53.6-69.1)	24.21(23.86-24.55)	53.4(52.6-54.1)	11.8	26						
121	10 wk			37.4(36.8-38.0)	82.4(81.1-83.8)	16.3	36						
122	12 wk			50.8(50.0-51.5)	111.9(110.2-113.5)	20.4	45						
123	14 wk					27.2	60						
124	16 wk					35.8	79						
125	18 wk					46.2	102						
126	20 wk					47.6	105						
127	22 wk					65.2	144						
128	24 wk					78.8	174						
129	26 wk					79.3	175						
130	28 wk					87.9	194						
Chicken:		Cornish, ♂		Cornish, ♀		White Leghorn, ♂		White Leghorn, ♀		New Hampshire, ♂		New Hampshire, ♀	
Age		kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb
131	Birth	0.032	0.07	0.032	0.07	0.036	0.08	0.036	0.08	0.041	0.09	0.036	0.08
132	1 wk	0.059	0.13	0.059	0.13	0.059	0.13	0.073	0.16	0.086	0.19	0.082	0.18
133	2 wk	0.109	0.24	0.105	0.23	0.123	0.27	0.118	0.26	0.154	0.34	0.154	0.34
134	3 wk	0.182	0.4	0.172	0.38	0.191	0.42	0.195	0.43	0.272	0.60	0.250	0.55
135	4 wk	0.268	0.59	0.256	0.56	0.268	0.59	0.272	0.60	0.404	0.89	0.363	0.80
136	5 wk					0.354	0.78	0.367	0.81	0.563	1.24	0.504	1.11
137	6 wk					0.449	0.99	0.436	0.96	0.735	1.62	0.640	1.41
138	7 wk					0.603	1.33	0.549	1.21	0.934	2.06	0.807	1.78
139	8 wk	0.727	1.6	0.636	1.4	0.689	1.52	0.640	1.41	1.152	2.54	0.948	2.09
140	9 wk					0.875	1.93	0.721	1.59	1.325	2.92	1.107	2.44
141	10 wk					0.944	2.08	0.776	1.71	1.628	3.59	1.284	2.83
142	12 wk	1.272	2.8	1.045	2.3	1.243	2.74	0.934	2.06	1.849	4.05	1.551	3.42
143	14 wk							1.107	2.44	2.554	5.63	1.828	4.03
144	16 wk	1.727	3.8	1.318	2.9			1.270	2.80	2.994	6.60	2.019	4.45
145	18 wk							1.402	3.09	3.293	7.26	2.254	4.97
146	20 wk	2.09	4.6	1.545	3.4			1.551	3.42	3.375	7.44	2.309	5.09

131. GROWTH: VERTEBRATES (Concluded)

Turkey:		Broad-breasted bronze, ♂		Broad-breasted bronze, ♀		Beltsville, small white, ♂		Beltsville, small white, ♀	
Age		kg	lb	kg	lb	kg	lb	kg	lb
147	Birth	0.054	0.12	0.050	0.11	0.045	0.10	0.045	0.10
148	1 wk	0.113	0.25	0.109	0.24	0.095	0.21	0.086	0.19
149	2 wk	0.204	0.45	0.195	0.43	0.181	0.40	0.163	0.36
150	4 wk	0.585	1.29	0.517	1.14	0.472	1.04	0.404	0.89
151	6 wk	1.252	2.76	0.998	2.20	0.921	2.03	0.721	1.59
152	8 wk	2.028	4.47	1.651	3.64	1.483	3.27	1.148	2.53
153	10 wk	2.939	6.48	2.354	5.19	2.205	4.86	1.674	3.69
154	12 wk	4.037	8.90	3.166	6.98	2.726	6.01	2.087	4.60
155	14 wk	4.922	10.85	3.715	8.19	3.357	7.40	2.608	5.75
156	16 wk	6.214	13.70	4.604	10.15	4.264	9.40	3.062	6.75
157	18 wk	6.985	15.40	5.121	11.29	4.704	10.37	3.357	7.40
158	20 wk	8.328	18.36	5.851	12.90	5.643	12.44	3.742	8.25
159	22 wk	8.850	19.51	6.083	13.41				
160	24 wk	10.614	23.40	6.836	15.07	7.438	16.20	4.382	9.66
161	26 wk	11.508	25.37	7.307	16.11	8.038	17.72	4.631	10.21
162	28 wk	12.633	27.85	7.625	16.81	9.008	19.86	4.740	10.45
163	30 wk					9.113	20.09	5.085	11.21
164	35 wk	14.610	32.21	7.793	17.18				
165	40 wk	14.814	32.66	8.437	18.60				

Age		Duck, white pekin		Goose, pilgrim				Quail, bob-white	
		kg	lb	♂ kg	♂ lb	♀ kg	♀ lb	kg	lb
166	Birth	0.059	0.13			0.07	0.17	0.004	0.01
167	1 wk	0.150	0.33	0.227	0.5	0.227	0.5	0.018	0.04
168	2 wk	0.458	1.01	0.635	1.4	0.589	1.3	0.027	0.06
169	3 wk	0.744	1.64	1.270	2.8	1.270	2.8	0.045	0.10
170	4 wk	1.148	2.53	1.905	4.2	1.769	3.9	0.063	0.14
171	5 wk	1.506	3.32	2.404	5.3	1.814	4.0	0.082	0.18
172	6 wk	2.005	4.42	3.039	6.7	2.585	5.7	0.095	0.21
173	8 wk	2.758	6.08	3.946	8.7	3.447	7.6	0.132	0.29
174	10 wk			4.264	9.4	3.719	8.2		
175	12 wk			5.035	11.1	4.218	9.3	0.159	0.35
176	16 wk			5.352	11.8	4.672	10.3	0.172	0.38

Lizard ⁴				Snake ⁵			
Black footless		Desert night		Skink, western		Blacksnake, pilot	
Sex & Age	mm	Sex & Age	mm	Sex & Age	mm	Sex & Age	mm
177	♂ < 1 yr (46-82)	♂ Birth (23-22-24)	29	♂ Birth (26-25-26)	307(267-331)	♂ 8 mo	228
178	2 yr (82-120)	1 yr	29	4 mo (40-37-43)	46 da	5 yr 8 mo	1115
179	3 yr (120-160)	2 yr	36	6 mo (45-41-49)	77 da	8 yr 3 mo	1282
180	Adult (>160)	♂ 3 yr (38-39)	10 mo	45	108 da	9 yr 1 mo	1308
181		♀ 3 yr (42-43)	11 mo	50		10 yr 2 mo	1320
182			20 mo	62		11 yr 2 mo	1371
183			24 mo	65		12 yr 2 mo	1397

Snake ⁵ (continued)				Turtle			
Massasauga, eastern		Racer, western striped		Rattlesnake, great basin		Water snake, queen	
Sex & Age	mm	Sex & Age	mm	Sex & Age	mm	Sex & Age	mm
184	♂ Birth 233	♂ 1 yr 627(579-655)	♂ 1 yr 457	♂ Birth 183(166-225)	♂ Birth (18-36)	♀ Birth 29-30	
185	1 yr 375	♀ 1 yr 587(538-622)	♀ 1 yr 450(419-503)	3 mo 231(196-255)	1st season (30-61)	♀ 30 yr 93	
186	3 yr 541	♂ 2 yr 790	♂ 2 yr 557(492-627)	1 yr 325(256-375)	2nd season (54-87)	41 yr 127	
187	Adult 637(541-731)	♂ 3 yr 864(807-919)	♀ 2 yr 554(530-574)	♂ > 2 yr 529(375-692)	3rd season (75-107)	64 yr 138	
188		♂ 4 yr 833	♂ 3 yr 655(609-711)	♀ > 2 yr 584(375-787)	4th season (91-115)		
189		♀ 4 yr 894(883-904)	♂ 4 yr 732		5th season (103-118)		
190		♂ 5 yr 859	♂ 4 yr 663(642-681)		6th season (110-115)		
191			♂ 6 yr 770(724-815)				
192			♀ 6 yr 666				

Fish:		Bass, rock		Carp		Catfish, channel		Crappie, black		Drum, fresh-water		Herring, lake		Paddlefish	
Age		kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb
193	1 yr	0.006	0.013	0.09	0.198	0.045	0.099	0.006	0.013	0.036	0.079	0.023	0.051	0.077	0.170
194	2 yr	0.028	0.062	0.45	0.992	0.135	0.298	0.045	0.099	0.135	0.298	0.04	0.088	1.35	2.975
195	4 yr	0.065	0.143	1.8	3.967	0.23	0.507	0.255	0.562	0.60	1.324	0.17	0.375	2.27	5.0
196	6 yr	0.165	0.364	2.5	5.510	0.68	1.50	0.37	0.816	1.18	2.601	0.23	0.507	3.40	7.494
197	8 yr	0.255	0.562	3.2	7.053	1.63	3.593	0.57	1.256	2.04	4.496	0.53	1.169	5.0	11.0
198	10 yr	0.38	0.838	5.1	11.240	4.3	9.477	0.68	1.499	5.10	11.24	0.71	1.565	6.8	14.99
199	Maximum	0.595	1.311	38	84	24	53	1.35	2.975	6.97	15.36	1.25	2.755	74	163

Fish: (continued)		Perch, yellow		Pike		Salmon, Atlantic		Sturgeon, lake		Sunfish, bluegill		Trout, lake		Whitefish, Lake Erie	
Age		kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb
200	1 yr	0.003	0.007	0.09	0.198	0.011	0.024	0.068	0.150	0.005	0.011	0.03	0.070	0.03	0.070
201	2 yr	0.03	0.070	0.27	0.595	0.033	0.073	0.136	0.299	0.026	0.057	0.14	0.309	0.085	0.187
202	4 yr	0.11	0.242	1.10	2.42	4.54	10.01	0.39	0.859	0.07	0.154	0.45	0.992	0.70	1.543
203	6 yr	0.23	0.507	2.10	4.63	16.0	35	0.72	1.587	0.17	0.375	1.13	2.49	1.36	2.997
204	8 yr	0.29	0.639	2.95	6.50			1.0	2.204	0.34	0.749	1.95	4.30	2.27	5.003
205	10 yr	0.37	0.815	4.50	9.92			1.4	3.09	0.34	0.749	3.82	8.42	2.78	6.127
206	Maximum	1.91	4.21	28	62	47	104	50	110	1.96	4.320	36	79	4.88	10.76

/4/ Snout-vent measurement. /5/ Total length measurement. /6/ Plastron measurement. /7/ Carapace measurement.

132. BODY AND ORGAN WEIGHTS: MAN

Values for organs are averages of fresh weight, in grams, determined as quickly as possible after removal. Body weight values, in kilograms, are averages, and are included only to show a relationship between average organ weights and average total body weights. When a single value for an organ weight is reported, it is an average for both sexes. When a value is a weight averaged over a period of two or more years, it is given at the earliest age of the period covered.

Age	Body Weight kg	Adre- nals g	Brain g	Heart g	Hypophy- sis g	Intes- tines ¹ g	Kidneys g	Liver g	Lungs g	Pan- creas g	Pineal Body g	Spleen g	Stomach ¹ g	Thymus g	Thyroid ² g	Epididy- mis g	Pro- state g	Seminal Vesicles g	Testes g	Ovaries g	Uterus g	Uterine Tubes g
1 Birth ♂	3.54	9.01	353	20	0.121	142	24	134	52	2.77	0.008	9.4	6.5	11.2	2.09(6.6)	0.24	0.82	0.050	0.67			
2 Birth ♀	3.43	9.03	347	19		149	22	137	51			9.4								0.29	4.70	0.29
3 0-3 mo ♂	5.92	4.66	435	19	0.161		30	143	69	3.54	0.044	14.6	10.9	19.3	1.71(3.18)	0.42	0.9	0.052	0.91			
4 0-3 mo ♀	5.62	4.60	411	17			27	133	64			11.4								0.63	2.88	0.26
5 3-6 mo ♂	8.4	3.61	600	27			43	184	94	5.38		18.9	14.1	22.9	2.11(4.4)				1.12			
6 3-6 mo ♀	7.9	4.37	534	25			37	178	93			15.9							0.45	3.00		
7 6-12 mo ♂	10.8	4.97	877	37			61	261	135	9.24		24	18.3	22.1	2.04(3.44)				1.39			
8 6-12 mo ♀	10.6	4.60	726	33			55	250	128			21							0.74	4.83		
9 1-2 yr ♂	12.2	3.68	971	47		409	74	343	170	13.54	0.053	32	27.1	26.0	2.53(5.24)	0.34	1.2	0.08	1.48			
10 1-2 yr ♀	11.9	3.19	894	42		375	69	322	175			29							0.98	4.01	0.29	
11 2-3 yr ♂	14.4	5.62	1076	59	0.232		94	459	246	19	0.081	44	37.9 ³	25.9	3.40(9.13)				1.93			
12 2-3 yr ♀	13.8	3.97	1012	55			91	429	244			41							1.12	2.30		
13 3-4 yr ♂	16.3		1179	71		648	101	531	305			49		26.4	4.9(11.22)	0.41	1.1		1.64			
14 3-4 yr ♀	16.2		1076	66		383	105	491	266			47										
15 4-5 yr ♂	18.5		1290	78	0.224		111	567	314	22	0.098	48	51.8 ⁴	24.4	5.24(15.15)							
16 4-5 yr ♀	18.0		1156	75			116	559	312			45								1.90	3.29 ⁵	
17 5-6 yr ♂	20.6	4.92	1275	89		691	108	592	261			57		23.3		0.50	1.3	0.099	1.67			
18 5-6 yr ♀	20.0	5.02	1206	83			116	591	320			50										
19 6-7 yr ♂	22.7		1313	98	0.299		155	661	400	29	0.131	67		26.0	7.05(14.4)							
20 6-7 yr ♀	22.2		1225	89			122	604	358			47										
21 7-8 yr ♂	25.1		1338	102			147	691	366			63		33.6								
22 7-8 yr ♀	24.6		1265	96		559	134	683	404			56								3.30	4.30	0.49
23 8-9 yr ♂	28		1294	128	0.366		141	808	405	27		74		27.7	9.3(18.34)							
24 8-9 yr ♀	27		1208	104			139	733	382			69										
25 9-10 yr ♂	31		1360	118			167	804	376			70		28.1					1.83 ⁶			
26 9-10 yr ♀	30		1226	125			157	863	358			66								7.59 ⁶		
27 10-11 yr ♂	33	6.86	1378	137	0.378		184	931	475	29	0.156	90	90 ⁷	28.9	8.69(23.2)	0.73	1.9	0.120	2.0			
28 10-11 yr ♀	34	7.40	1247	144			189	905	571			112										
29 11-12 yr ♂	37		1348	149			178	902	466			80		30.8								
30 11-12 yr ♀	38		1259	127			143	840	535			83										
31 12-13 yr ♂	41		1383	154	0.460		185	987	459	35		85		23.6	14.8(24.7)	0.84	3.3		6.96			
32 12-13 yr ♀	43		1256	131			193	1048	682			101										
33 13-14 yr ♂	46		1382	172		1000	215	1103	505			107		34.0					7.17 ⁸			
34 13-14 yr ♀	46		1243	164			188	998	602			94								4.12 ⁸	11.60 ⁸	
35 14-15 yr ♂	52		1356	203			250	1166	693	68		109		26.5	14.5(26)	1.64	4.3	0.90	15.56			
36 14-15 yr ♀	50		1318	184			226	1209	517			127								6.03	32	1.05
37 15-16 yr ♂	58	9.47	1407	203		1460	251	1228	692			145		28.8								
38 15-16 yr ♀	52	11.38	1271	215			245	1349	709			131										
39 16-17 yr ♂	62		1419	234	0.520		253	1448	747	85	0.137	166	129 ⁹		16.6(28)		8.8		23.5			
40 16-17 yr ♀	53		1300	243			261	1414	627			172										
41 17-18 yr ♂	65		1409	252			297	1515	777			148										
42 17-18 yr ♀			1254	228			270	1417	695			123										
43 18-19 yr ♂	67		1426	260		1527	303	1702	848			169			18.3(29)							
44 18-19 yr ♀	55		1312	242			276	1541	655			151										
45 19-20 yr ♂	69		1430	283			295	1570	1036			153										
46 19-20 yr ♀			1294	257			272	1433	785			138								7.87 ¹⁰	47.0 ¹⁰	
47 20-30 yr ♂	71	13.75	1355	312	0.625	1600	313	1838	953		0.171	204		19.9	25(38)	4.0	16.6		28.3			
48 20-30 yr ♀	56	13.80	1220	273			257	1437	793			168								10.16	77.5	2.13
49 30-40 yr ♂	72	11.41	1365			1570	323	1872	1169			168		19.7					27.2			
50 30-40 yr ♀	60	11.57	1228			1550	250	1462	886			164								9.25	78.0	
51 40-50 yr ♂		11.52	1357			1800	316	1888				179		18.7					27.0			
52 40-50 yr ♀	65	10.17	1227				258	1570				172								6.15	100.5	
53 50-60 yr ♂		12.48	1360				294	1848				127								27.4		
54 50-60 yr ♀	67	12.01	1212				254	1464				133								5.73	95.8	
55 60-70 yr ♂		13.93	1319			1600	293	1728				132		13.4						24.3		
56 60-70 yr ♀	65	12.95	1194				218	1400				129								2.87	63.3	
57 70-80 yr ♂		11.85	1290			1500	253	1426				123								21.6		
58 70-80 yr ♀	61	10.42	1145			1400	236	1263				121								3.99	59.0	

/1/ Body weights of the individuals whose organ weights are given in this column were considerably lower than those shown in the body weight column for the various age groups. /2/ Normal thyroid values followed, in parentheses, by values for thyroid weight in geographical goiter areas. /3/ 2-4 yr. /4/ 4-7 yr. /5/ 3-5 yr. /6/ 6-10 yr. /7/ 7-14 yr. /8/ 11-14 yr. /9/ 14-20 yr. /10/ 15-20 yr.

133. BODY AND ORGAN WEIGHTS: VERTEBRATES

Values are based on fresh weight for adult organs, determined immediately after death of the organism, and are grams/100 grams body weight.

Species	Sex and Number	Body wt. kg	Adrenals g/100g	Brain g/100g	Eyes g/100g	Heart g/100g	Kidneys g/100g	Liver g/100g	Lungs g/100g	Spleen g/100g	Stomach & Intestines g/100g	Thyroid g/100g
Mammalia												
Man (<i>Homo sapiens</i>)												
1 Australian aborigine	♂1	76	0.005	1.77								0.005
2 Chinese	♂1	84	0.009	1.76		0.66	0.37	2.43		0.21		0.02
3 Filipino	♂1	43		2.57		0.46						0.06
4 Indian, Maya Quiche	♂1	42	0.03	3.02		0.52	0.44	2.48	3.13	0.14		0.08
5 Indian, Maya Quiche	♀1	46	0.02	2.18		0.49						0.02
6 Negro	♂7	47	0.03	2.73		0.81	0.51	2.81				0.06
7 White, American	♂7	67	0.02	1.96		0.42	0.41	2.30	0.73	0.25		0.04
8 White, European	♂4	49	0.03	2.53		0.64						0.03
9 Agouti, brown (<i>Dasyprocta punctata</i>)	♂♀5	2.6	0.03	0.58	0.50	0.51	0.59	2.84	0.22			
10 Antbear (<i>Cyclops didactylus</i>)	♀1	0.09	0.84	4.77								
11 Anteater (<i>Tamandua tetradactyla</i>)	♂♀4	2.2		1.09		0.03	0.82	2.64	1.05	0.14		
12 Armadillo (<i>Dasybus novemcinctus</i>)	♂♀12	3.3	0.03	0.25		0.28	0.48		0.70	0.22		0.009
13 Ass (<i>Equus asinus</i>)	♀1	150	0.01	0.27		0.55	1.04	0.84	0.83	0.39		0.006
14 Bat, vampire (<i>Desmodus rotundus</i>)	♂♀5	0.028	0.04	3.34								0.04
15 Bear, brown (<i>Ursus americanus</i>)	♂1	550	0.001				0.03					0.004
16 Bear, grizzly (<i>U. horribilis</i>)	♀1	140	0.04	0.16		0.79	0.38			0.21		0.04
17 Beaver (<i>Castor canadensis</i>)	♂1;♀1	5	0.009	0.45		0.43	1.08	3.03	0.97			
18 Bison, American (<i>Bison bison</i>)	♀1	55	0.01	0.61	0.08	0.66	0.47	1.27	2.17	0.27		0.09
19 Buffalo, African (<i>Syncerus caffer</i>)	♂3;♀1	700	0.005	0.09	0.008	0.47	0.24	0.98	0.94	0.33	20.90	0.005
20 Bushbok (<i>Tragelaphus scriptus</i>)	♂1;♀1	44	0.01	0.37	0.11	0.76	0.40	1.95	1.64	0.26	12.62	0.01
21 Camel, bactrian (<i>Camelus bactrianus</i>)	♂1	450	0.005	0.12	0.02							
22 Caribou, ground (<i>Rangifer arcticus</i>)	♂3;♀1	98	0.004	0.30	0.04	0.90	0.13	1.83	2.10	0.26		
23 Cat, domestic (<i>Felis catus</i>)	♂7;♀3	3.3	0.02	0.77	0.32	0.45	1.07	3.59	1.04	0.29	10.37	0.01
24 Cattle, Holstein (<i>Bos taurus</i>)	♂5	900	0.005	0.05		0.37	0.20	0.92	0.69	0.15	3.14	0.010
25 Cattle, Holstein (<i>B. taurus</i>)	♀198	600	0.006	0.07		0.37	0.24	1.20	0.72	0.16	4.83	0.006
26 Cheetah (<i>Acinonyx jubatus</i>)	♂2	21	0.009	0.39	0.16	0.51	0.47	3.22	1.16	0.15		0.02
27 Chimpanzee (<i>Pan troglodytes</i>)	♂1	52	0.02	0.84		0.48						0.009
28 Chimpanzee (<i>P. troglodytes</i>)	♀1	44	0.02	0.74		0.50	0.48	2.75	1.36		14.09	0.01
29 Chipmunk (<i>Tamias striatus</i>)	♂2	0.07	0.04	2.96	0.74	7.96	0.10	7.4	0.96	0.29	6.2	0.04
30 Coati (<i>Nasua nasua</i>)	♂2	5.1	0.009	0.66	0.04	0.38	0.08	1.63	0.47	0.07		0.03
31 Coyote (<i>Canis latrans</i>)	♀2	8.5				0.85	0.94	3.44	0.72	0.17		
32 Deer, white-tailed (<i>Odocoileus virginianus</i>)	♂1	65		0.32		0.97		1.57				
33 Dog (<i>Canis familiaris</i>)	♂2;♀2	13	0.01	0.59	0.10	0.85	0.30	2.94	0.94		4.83	0.02
34 Elephant (<i>Loxodonta africana</i>)	♂1	6600	0.01	0.08	0.001	0.39	0.27	1.62	2.08		13.88	0.01
35 Fox, gray (<i>Urocyon cinereoargenteus</i>)	♂1	3.8	0.01	0.99	0.11	0.58	0.46	1.35	0.51		11.31	
36 Fox, red (<i>Vulpes fulva</i>)	♀1	4.6	0.01	1.15	0.09	0.90						0.003
37 Gazelle (<i>Gazella thomsoni</i>)	♂2	24	0.008	0.38	0.11	1.00	0.43	2.15	1.15			0.007
38 Giraffe (<i>Giraffa camelopardalis</i>)	♂1	1200	0.006	0.06	0.01	0.41	0.18	1.56	0.99	0.18	10.65	0.005
39 Goat (<i>Capra hircus</i>)	♂1	28		0.41	0.11			1.90				
40 Gorilla (<i>Gorilla gorilla</i>)	♂1	180	0.02									0.003
41 Guinea pig (<i>Cavia porcellus</i>)	♂58	0.26	0.07	1.33		0.53	1.17	5.14	1.18			
42 Guinea pig (<i>C. porcellus</i>)	♀10	0.43	0.08	0.92	0.24	0.39	0.86	3.86	1.07	0.21		0.02
43 Hamster, golden (<i>Mesocricetus auratus</i>)	♂2;♀2	0.12	0.02	0.88	0.18	0.47	0.53	5.16	0.46			0.006
44 Hare, African (<i>Lepus capensis</i>)	♀1	2.9	0.02	0.35	0.25	1.02	0.42	1.77	0.61		10.07	0.006
45 Hippopotamus (<i>Hippopotamus amphibius</i>)	♀1	1350	0.004	0.05	0.003	0.34	0.23	1.75	0.84	0.23	27.70	0.008
46 Horse, Percheron (<i>Equus caballus</i>)	♂1	635	0.006	0.10	0.02	0.88	0.27	1.34	0.90	0.54		0.006
47 Horse, Percheron (<i>E. caballus</i>)	♀1	770	0.004	0.08	0.02	0.61	0.23	0.87	0.70	0.20		0.007
48 Hyena, spotted (<i>Crocuta crocuta</i>)	♂2	62	0.02	0.28	0.06	0.72	0.64	5.12	10.92		10.91	0.01
49 Hyrax (<i>Heterohyrax brucei</i>)	♂1	0.75	0.02	1.64		0.48	0.86	4.20	0.74		34	0.01
50 Jackal (<i>Canis mesomelas</i>)	♂2	2.8	0.02	1.61	0.24	0.75	0.81	4.30	1.05		10.81	0.03
51 Jaguar (<i>Felis onca</i>)	♀1	34	0.02	0.43	0.05	0.54	0.48	2.59	1.67	0.18		0.004
52 Kinkajou (<i>Potos flavus</i>)	♀1	2.6	0.007	1.18	0.07	0.54		3.76	2.99			0.02
53 Lemming, rock (<i>Dicrostonyx rubricatus</i>)	♂4	0.05	0.03	0.17	0.28	0.59	1.48	5.05	1.59	0.40		0.008
54 Leopard (<i>Panthera pardus</i>)	♂1	48	0.01	0.28	0.06	0.42		1.87	1.04	0.22		0.10
55 Lion (<i>P. leo</i>)	♂4	125	0.01	0.19		0.85			2.12			
56 Lion (<i>P. leo</i>)	♀3	97	0.01	0.20	0.04	0.54	0.53	3.24	2.06	0.22		
57 Lynx (<i>Lynx baileyi</i>)	♂1	7.4	0.08				0.33					0.004
58 Manatee (<i>Trichechus manatus</i>)	♂1	425		0.08	0.001	0.29		1.30	0.72			0.01
59 Manatee (<i>T. manatus</i>)	♀1	560	0.002		0.01	0.22	0.24	1.12	0.67			0.01
60 Mole (<i>Scalopus aquaticus</i>)	♂1	0.04	0.04	2.93		0.69	1.59	3.91	1.86			0.02
61 MongOOSE (<i>Ichneumia albicauda</i>)	♂1	4.4	0.01	0.64	0.09	0.64	0.79	1.39	1.32		6.25	0.004
62 Monkey, blackhowler (<i>Alouatta palliata</i>)	♂♀28	6.2	0.01	0.81		0.33	0.58	3.25	0.63	0.74		
63 Monkey, rhesus (<i>Macaca mulatta</i>)	♂4	3.3	0.02	2.78	1.06	0.38		2.09				0.02
64 Monkey, rhesus (<i>M. mulatta</i>)	♀7	3.6	0.03	2.57		0.34			1.89			0.01
65 Mouse, jumping (<i>Zapus hudsonicus</i>)	♂1;♀3	0.018	0.04	3.57	0.14	1.03	1.26	5.63	1.34			0.01
66 Mouse, meadow (<i>Microtus drummondii</i>)	♂♀67	0.023	0.03	0.29	0.10	0.68	1.53	4.56	1.70			0.01
67 Muskrat (<i>Ondatra zibethica</i>)	♂1	0.90	0.01	0.59	0.21	0.36	0.83	2.44	0.48		1.95	0.001
68 Opossum, woolly (<i>Philander laniger</i>)	♂1;♀1	190	0.53			1.58	2.10	4.74	1.58	0.79		
69 Porcupine (<i>Erethizon dorsatum</i>)	♂1;♀3	2.9	0.01	0.78	0.09	0.55	0.96	4	0.98			0.02
70 Porpoise (<i>Phocaena phocaena</i>)	♂1	140	0.007	1.22	0.04	0.52		2.08	3.69	0.04	9.28	0.01
71 Rabbit, giant Flemish (<i>Lepus spp</i>)	♂2	3.7	0.01	0.29		0.29	0.61	2.66				0.02
72 Rabbit, giant Flemish (<i>Lepus spp</i>)	♀22	2.5	0.02	0.40		0.35	0.70	3.19	0.53			
73 Raccoon (<i>Procyon lotor</i>)	♂1	5.2	0.02	0.82		0.81	0.68	3.58	3.58	0.28		
74 Raccoon (<i>P. lotor</i>)	♀1	2.2	0.07	1.51	0.15	0.89	1.61	6.29	0.87			0.008
75 Rat, Norway (<i>Rattus norvegicus</i>)	♂2;♀1	0.25	0.05	1.22	0.10	0.52	1.09	3.35	0.79	0.29	2.52	0.001
76 Reebuck (<i>Redunca reeduna</i>)	♂2	31	0.006	0.34	0.10	0.76	0.32	1.65	1.34			0.004
77 Seal, ringed (<i>Phoca hispida</i>)	♂3;♀2	39	0.007	0.63	0.18	0.73	0.70	2.81	1.85	0.32		0.008
78 Shrew (<i>Blarina brevicauda</i>)	♂29	0.02	0.02	1.87	0.009	1.02	1.08	5.81	2.24			0.01
79 Shrew (<i>B. brevicauda</i>)	♀39	0.017	0.02	2.11	0.006	1.05	1.25	5.45	2.19			0.01
80 Skunk (<i>Mephitis mephitis</i>)	♂1;♀2	2.1	0.01	0.33		0.58	0.28	2.69	1.59			0.004

133. BODY AND ORGAN WEIGHTS: VERTEBRATES (Concluded)

Values are based on fresh weight for adult organs, determined immediately after death of the organism, and are grams/100 grams body weight.

Species	Sex and Number	Body wt. kg	Adrenals g/100g	Brain g/100g	Eyes g/100g	Heart g/100g	Kidneys g/100g	Liver g/100g	Lungs g/100g	Spleen g/100g	Stomach & Intestines g/100g	Thyroid g/100g
Mammalia (concluded)												
81 Sloth, three-toed (<i>Bradypus tridactylus</i>)	♂26	1.8	0.01	0.75								
82 Squirrel, red (<i>Sciurus hudsonicus</i>)	♂4	0.18	0.03	2.57	0.27	0.86	0.62	2.18	1.45			0.01
83 Squirrel, red (<i>S. hudsonicus</i>)	♀4	0.25	0.03	2.02	0.21	0.73	0.53	2.68	1.28			0.01
84 Steinbok (<i>Raphicerus campestris</i>)	♂2	8.6	0.01	0.57	0.17	0.84	0.45	2.03	1.74		6.38	0.01
85 Swine (<i>Sus scrofa</i>)	♀36	102	0.004			0.32	0.26	1.51		0.13	1.95	0.007
86 Tapir (<i>Tapirella bairdii</i>)	♂1;♀1	11.4	0.02			0.85	1.30	3.07	2.10	1.12		
87 Tiger (<i>Panthera tigris</i>)	♀1	160	0.01	0.14		0.27		1.14	0.64	0.57		
88 Walrus (<i>Odobenus rosmarus</i>)	♂1;♀3	600	0.002	0.17	0.003	0.68	0.68	2.92	1.36		4.42	0.01
89 Warthog (<i>Phacochoerus aethiopicus</i>)	♂1	65	0.01	0.19	0.03	0.50	0.46	2.30	0.84		15.23	0.005
90 Weasel, arctic (<i>Mustela arctica</i>)	♂3;♀1	0.18	0.01	2.80	0.08	1.71	0.99	4.74	2.08			0.05
91 Whale, white (<i>Delphinapterus leucas</i>)	♂4	447	0.006	0.52	0.007	0.55	0.49	1.52	2.70	0.04	2.70	0.02
92 Whale, white (<i>D. leucas</i>)	♀2	300	0.009	0.78	0.007	0.57	0.61	1.59	2.62	0.05	3.06	0.02
93 Wildebeest (<i>Connochaetes taurinus</i>)	♂2	210	0.003	0.21		0.62	0.23	1.07	1.34		17.54	0.005
94 Wolf (<i>Canis lupus</i>)	♂1	22	0.01	0.52	0.08	1.08	0.82	2.76	3.56			
95 Zebra (<i>Equus quagga</i>)	♂3;♀1	280	0.008	0.20	0.03	1.42	0.35	1.67	0.80	0.41		0.007
Aves												
96 Blackbird (<i>Quiscalus quiscula</i>)	♀1	0.08	0.02	3.56	0.23	0.14	0.16	3.21	0.21	0.06	7.78	0.01
97 Bluebird (<i>Sialia sialis</i>)	♂1;♀1	0.03	0.55	4.24		1.39						0.02
98 Buzzard, steppe (<i>Buteo vulpinus</i>)	♂1	0.56	0.05	1.41		0.82	0.60	1.94	0.83			0.03
99 Catbird (<i>Dumetella carolinensis</i>)	♀1	0.03	0.01	0.43		0.99			1.84			0.01
100 Canary (<i>Serinus canarius</i>)	♂1;♀1	0.016	0.04	4.72	1.75	1.29	0.16	5.39	0.15	0.11	14.17	0.008
101 Cowbird (<i>Molothrus ater</i>)	♀1	0.07	0.02	4.08		1.61						0.02
102 Crane, gray (<i>Grus canadensis</i>)	♂1	1.6	0.01	0.52	0.66	1.15	0.71	1.78	0.93	0.04	4.76	0.008
103 Crow (<i>Corvus brachyrhynchos</i>)	♂1	0.33	0.02	2.76		0.95			2.96			0.01
104 Duck, pintail (<i>Anas acuta</i>)	♀1	0.67	0.01	0.74	0.25	1.24	1.21	4.53	2.56	0.13	14.84	0.008
105 Eagle, tawny (<i>Aquila rapax</i>)	♂2;♀3	2.4	0.45	0.59	1.34	0.63	0.50	1.82	1.04		6.36	0.01
106 Egret, great white (<i>Casmerodius albus</i>)	♀1	10	0.02	0.59		0.90	0.79	3.20	3.21		13.11	0.01
107 Flamingo (<i>Phoeniconaias minor</i>)	♂3;♀2	15	0.02	0.49	0.22	0.94	1.18	2.68	1.47			0.03
108 Fowl, domestic (<i>Gallus domesticus</i>)	♂8	0.73	0.009	0.40	0.58	0.57	0.62	2.21	0.60	0.13		0.01
109 Fowl, domestic (<i>G. domesticus</i>)	♀16	0.61	0.01	0.44	0.58	0.63	0.68	2.36	0.61	0.15		0.01
110 Fowl, white leghorn, "germ-free" ¹	?	0.9-1.2	0.009			0.35		1.53	0.51			
111 Goose, Egyptian (<i>Alopochen aegypticus</i>)	♀1	1.9	0.02	0.39		0.96	0.50	1.77	1.80			0.02
112 Guinea fowl (<i>Numida meleagris</i>)	♂1	1.6	0.02	0.26		0.88	0.45	1.76	1.79			0.02
113 Gull, herring (<i>Larus argentatus</i>)	♀2	0.53	0.02	0.95	1.45	0.98		5.12				0.007
114 Hawk, red-tailed (<i>Buteo borealis</i>)	♀3	1.0	0.01	0.97	2.06	0.67	0.30	1.37	0.9		1.79	0.09
115 Hummingbird (<i>Amazilia tzacatl</i>)	♀1	0.005	0.007	4.16	2.50	2.37	0.81	5.23	0.20			0.009
116 Ostrich, masai (<i>Struthio camelus</i>)	♂1	125	0.02	0.03	0.08	0.98		1.66	2.36			
117 Owl, horned (<i>Buteo virginianus</i>)	♂1	1.2	0.01	1.16		0.73			0.91			0.007
118 Partridge (<i>Francolinus sephaena</i>)	♂1	0.21	0.02	0.72		0.70	1.30	4.16				0.009
119 Pelican (<i>Pelecanus occidentalis</i>)	♀2	3.3	0.03	0.54	0.38	0.67		2.22	0.91		7.75	0.005
120 Pheasant (<i>Phasianus colchicus</i>)	♂1	0.62	0.02	0.53	0.85	0.90	0.77	1.46			9.04	0.008
121 Pigeon (<i>Columba livia</i>)	♂3;♀1	0.27	0.16	0.95		1.75		1.76				0.11
122 Raven (<i>Corvus corax</i>)	♀1	1.25		2.81		0.85	0.71					0.009
123 Robin (<i>Turdus migratorius</i>)	♂2	0.07	0.03	3.01		1.46			2.42			0.01
124 Sparrow (<i>Passer domesticus</i>)	♂75	0.024	0.03	4.36	1.95	1.73	1.46	5.12	1.56	0.18	11.45	0.02
125 Sparrow (<i>P. domesticus</i>)	♀11	0.023	0.03	4.38	2.23	1.69	1.53	4.67	1.72	0.18	11.53	0.02
126 Starling (<i>Sturnus vulgaris</i>)	♂15	0.06	0.02	3.26	1.46	1.62	1.71	3.46	1.87	0.11	9.15	0.01
127 Starling (<i>S. vulgaris</i>)	♀10	0.06	0.02	3.13	1.80	1.49	1.85	3.76	1.87	0.07	9.69	0.01
128 Stork, European (<i>Ciconia ciconia</i>)	♂2;♀1	3.3	0.01	0.47	0.51	0.92	0.65	1.92	1.11			0.01
Reptilia												
129 Alligator (<i>Alligator mississippiensis</i>)	♂2	190	0.004	0.007	0.01	0.15		0.38	0.54	0.07	2.95	0.006
130 Crocodile (<i>Crocodylus acutus</i>)	♂1;♀1	110	0.004	0.001		0.12		1.02	1.00			0.004
131 Iguana lizard (<i>Iguana iguana</i>)	♀1	1.3	0.02			0.19		2.49	0.28		3.18	0.009
132 Lizard (<i>Lacerta viridis</i>)	♂15	0.05	0.04	0.24		0.12	0.12	5		0.16		0.02
133 Snake, black (<i>Coluber constrictor</i>)	♂1;♀2	0.43	0.03	0.07	0.05	0.22	0.60	0.60	0.80	0.18	2.79	0.02
134 Snake, boa (<i>Boa imperator</i>)	♀1	1.8	0.008	0.02	0.03	0.31	0.52	1.66	0.76			0.008
135 Snake, green (<i>Zamenis viridis</i>)	♂3;♀3	0.022	0.36	0.95			8.77	2.19		0.57		0.20
136 Snake, python (<i>Python molurus</i>)	♂1	6.1	0.04	0.02	0.02	0.30						0.02
137 Snake, water moccasin (<i>Ancistrodon pisci</i>)	♀1	0.73	0.14	0.09	0.08	0.65	1.85	8.85	3.12	0.76	41.24	0.07
138 Toad, horned (<i>Phrynosoma cornutum</i>)	♂2;♀3	0.025	0.03	0.52	1.28	0.44						
139 Turtle (<i>Aromochelys tristycha</i>)	♂1	0.12				0.43	0.43	2.8	0.85	0.18	2.729	
140 Turtle (<i>A. tristycha</i>)	♀2	0.09				0.48	0.47	2.9	0.76	0.17		
141 Turtle (<i>Testudo graeca</i>)	♂30	0.32	0.009	0.09			0.48	2.66		0.06		0.01
142 Turtle, cumberland (<i>Chrysemys elegans</i>)	♂21	0.84				0.32	0.32	5.43	1.07	0.22	6.23	
143 Turtle, cumberland (<i>C. elegans</i>)	♀1	0.86				0.31	0.36	5.92	0.84	0.47	7.32	
Amphibia												
144 Frog, bull (<i>Rana catesbeiana</i>)	♂7	0.49	0.02	0.93	0.48	0.32	0.29	2.75	0.53	0.07	4.72	0.007
145 Frog, leopard (<i>R. pipiens</i>)	♂10	0.036				0.43	0.43	2.81	0.85	0.18	3.50	
146 Frog, leopard (<i>R. pipiens</i>)	♀19	0.038				0.48	0.47	2.88	0.76	0.17	3.77	
Pisces												
147 Barracuda (<i>Sphyrna barracuda</i>)	♂3;♀3	8.8		0.04	0.44	0.24	1.82	0.69		0.15	4.17	0.002
148 Carp (<i>Cyprinus carpio</i>)	♂2;♀4	1.05		0.12	0.28	0.15	0.55			0.23	7.92	0.0008
149 Codfish (<i>Gadus morrhua</i>)	♀1	10.6		0.05	0.6	0.15	0.19	1.52		0.95	5.47	0.006
150 Haddock (<i>G. aeglefinus</i>)	♀6	3.3		0.06	0.2	0.17	0.34	4.05		0.08	8.90	0.002
151 Mackerel (<i>Scomber vernalis</i>)	♂1	0.76		0.08								
152 Mackerel (<i>S. vernalis</i>)	♀2	1.5		0.11	0.54	0.20		0.43		0.12	0.20	0.002
153 Perch (<i>Perca flavescens</i>)	♂6	0.17		0.15	0.55	0.23	0.27	0.88		0.09	2.90	0.002
154 Perch (<i>P. flavescens</i>)	♀1	0.19		0.17	0.73	0.77		1.54			4.12	0.001
155 Pike (<i>Esox lucius</i>)	♂4;♀3	0.42		0.12	1.15	0.15	0.42	0.86		0.09	5.10	0.002
156 Salmon (<i>Salmo salar</i>)	♂3	3.4		0.03	0.23	0.36	1.05	2.02		0.32	6.29	0.005
157 Salmon (<i>S. salar</i>)	♀5	5.4		0.02	0.15	0.19	0.74	1.73		0.22	4.30	0.0007
158 Trout, rainbow (<i>Salmo irideus</i>)	♂2	0.26		0.17	0.69	0.17	0.55	0.99		0.21	9.58	0.003
159 Trout, rainbow (<i>S. irideus</i>)	♀4	0.22		0.19	0.70	0.13	0.50	0.99		0.27	8.89	0.002

¹/1/A discussion of the meaning of "germ-free" is given in the Lobund report of the University of Notre Dame.

134. FISH: WORLD RECORDS

Species	Caught by Rod and Reel					Caught by Any Method			
	Weight		Length	Girth	Location	Date	Weight		Location
	lb	oz	in.	in.			lb	oz	
Fresh-water Records ¹									
1 Black bass, largemouth (<i>Micropterus salmoides</i>)	22	4	32½	28½	Montgomery Lake, Ga.	1932	Same		
2 Black bass, smallmouth (<i>M. dolomieu</i>)	10	8	22½	21½	Wheeler Dam, Ala.	1950	Same		
3 Bluegill sunfish (<i>Lepomis macrochirus</i>)	4	12	15	18½	Ketona Lake, Ala.	1950	Same		
4 Bullhead, black (<i>Ameiurus melas</i>)	8		24	17½	Lake Waccabuc, N. Y.	1951	Same		
5 Carp (<i>Cyprinus carpio</i>)	55	5	42	31	Clearwater Lake, Minn.	1952	83	8	Pretoria, S. Africa
6 Catfish, blue (<i>Ictalurus furcatus</i>)	94	8	56	35	James River, S. D.	1949	Same		
7 Catfish, channel (<i>I. lacustris</i>)	55		50	27	James River, S. D.	1949	Same		
8 Charr, arctic (<i>Salvelinus alpinus</i>)	11	8	30	17	Richmond Gulf, Hud. Bay	1950	Same		
9 Gar, alligator (<i>Lepisosteus spatula</i>)	279		93		Rio Grande River, Tex.	1951	Same		
10 Muskellunge (<i>Esox masquinongy</i>)	69	11	63½	31½	Chippewa Flowage, Wis.	1949	102		Minocqua Lake, Wis.
11 Perch, white (<i>Morone americana</i>)	4	12	19½	13	Messalonskee Lake, Me.	1949	Same		
12 Perch, yellow (<i>Perca flavescens</i>)	4	3½			Bordentown, N. J.	1865	Same		
13 Pickerel, eastern chain (<i>Esox niger</i>)	9		30	15	Green Pond, N. J.	1948	9	5	Pontoosuc Lake, Mass.
14 Pike, northern (<i>E. lucius</i>)	46	2	52½	25	Sacandaga Res., N. Y.	1940	Same		
15 Pike, walleyed (<i>Stizostedion vitreum</i>)	22	4	36¼	21	Fort Erie, Ontario	1943	Same		
16 Salmon, Atlantic (<i>Salmo salar</i>)	79	2			Tanaelv, Norway	1928	103	2	River Devon, Scotland
17 Salmon, chinook (<i>Oncorhynchus tshawytscha</i>)	83				Umpqua River, Ore.	1910	126	8	Petersburg, Alaska
18 Salmon, landlocked (<i>Salmo sebago</i>)	22	8	36		Sebago Lake, Me.	1907	35		Crooked River, Me.
19 Salmon, silver (<i>Oncorhynchus kisutch</i>)	31				Cowichan Bay, B. C.	1947	Same		
20 Trout, brook (<i>Salvelinus fontinalis</i>)	14	8			Nipigon River, Ontario	1916	Same		
21 Trout, brown (<i>Salmo trutta</i>)	39	8			Loch Awe, Scotland	1866	40		Great Lake, Tasmania
22 Trout, cut-throat (<i>S. clarkii</i>)	41		39		Pyramid Lake, Nev.	1925	Same		
23 Trout, Dolly Varden (<i>Salvelinus malma</i>)	32		40½	29½	L. Pend Oreille, Id.	1949	Same		
24 Trout, golden (<i>Salmo agria-bonita</i>)	11		28	16	Cook's Lake, Wyo.	1948	Same		
25 Trout, lake (<i>Cristivomer namaycush</i>)	63	2	51½	32½	Lake Superior	1952	80		Mackinaw, Mich.
26 Trout, rainbow ² (<i>Salmo gairdneri</i>)	37		40½	28	Lake Pend Oreille, Id.	1947	42		Corbett, Ore.
27 Trout, Sunapee (<i>Salvelinus aureolus</i>)	11	8	33	17½	Lake Sunapee, N. H.	1954	Same		
Salt-water Records ³									
28 Albacore (<i>Thunnus germon</i>)	66	4	63½	46½	Catalina, Calif.	1912	Same		
29 Amberjack (<i>Seriola lalandi</i>)	119	8	63½	46½	Rio de Janeiro, Brazil	1952	146		Flatts Inlet, Bermuda
30 Barracuda (<i>Sphyræna barracuda</i>)	103	4	66	31½	West End, Bahamas	1932	Same		
31 Bass, Calif. white sea (<i>Cynoscion nobilis</i>)	83	12	65½	34	Baja, Mexico	1953	Same		
32 Bass, channel (<i>Sciaenops ocellata</i>)	83		52	29	Cape Charles, Va.	1949	Same		
33 Bass, giant black sea (<i>Stereolepis gigas</i>)	483		87	73	Coronado Is., Mexico	1951	800		Avalon, Calif.
34 Bass, giant sea (<i>Promicropus itaiara</i>)	551		100		Galveston Bay, Tex.	1937	Same		
35 Bass, sea (<i>Centropomus striatus</i>)	8		22	19	Nantucket Sound, Mass.	1951	Same		
36 Bass, striped (<i>Roccus saxatilis</i>)	73		60	30½	Vineyard Sound, Mass.	1913	125		Edenton, N. C.
37 Blackfish (<i>Tautoga onitis</i>)	21	6	31½	23½	Cape May, N. J.	1954	22	8	Near New York
38 Bluefish (<i>Pomatomus saltatrix</i>)	24	3	41	22	San Miguel, Azores	1953	27		Nantucket, Mass.
39 Bonefish (<i>Albula vulpes</i>)	18	2	41½	18	Mana, Kauai, T. H.	1954	Same		
40 Bonito, oceanic (<i>Katsuwonus pelamis</i>)	39	15	39	28	Walker Cay, Bahamas	1952	Same		
41 Cobia (<i>Rachycentron canadus</i>)	102		70	34	Cape Charles, Va.	1938	Same		
42 Cod (<i>Gadus callarias</i>)	57	8	56		Ambrose Lightship, N. Y.	1949	Same		
43 Dolphin (<i>Coryphaena hippurus</i>)	75	8	50	21	Mafia Channel, E. Africa	1950	Same		
44 Drum, black (<i>Pogonias cromis</i>)	88		48		Delaware Bay, N. J.	1954	146		St. Augustine, Fla.
45 Flounder, summer ⁴ (<i>Paralichthys dentatus</i>)	20		37	32	Oak Beach, N. Y.	1948	26		Noank, Conn.
46 Kingfish ⁵ (<i>Scomberomorus cavalla</i>)	76	8	63	31	Bimini, Bahamas	1952	100		
47 Marlin, blue (<i>Makaira nigricans ampla</i>)	742		154½	68	Bimini, Bahamas	1949	1200		Havana, Cuba
48 Marlin, Pacific black (<i>M. nigricans marlina</i>)	1560		174	81	Cabo Blanco, Peru	1953	Same		
49 Marlin, silver (<i>M. nigricans tahitiensis</i>)	755		163½	65½	Pinas Bay, Panama	1953	Same		
50 Marlin, striped (<i>M. mitsukurii</i>)	692		161		Balboa, Calif.	1931	Same		
51 Marlin, white (<i>M. albidus</i>)	161		104	33	Miami Beach, Fla.	1938	Same		
52 Permit (<i>Trachinotus goodei</i>)	42	4	43	33½	Boca Grange, Fla.	1953	Same		
53 Pollack (<i>Pollachius virens</i>)	32	4	44	26½	Belmar, N. J.	1953	Same		
54 Roosterfish (<i>Nematistius pectoralis</i>)	100		54	32	Cabo Blanco, Peru	1954	Same		
55 Sailfish, Atlantic (<i>Istiophorus americanus</i>)	123		124	32½	Walker Cay, Bahamas	1950	Same		
56 Sailfish, Pacific (<i>I. greyi</i>)	221		129		Galapagos Islands	1947	Same		
57 Sawfish (<i>Pristis pectinatus</i>)	736		175		Galveston, Tex.	1938	1500		Aransas Pass, Tex.
58 Shark, mako, Atlantic (<i>Isurus oxyrinchus</i>)	1000		144		Mayor Island, N. Z.	1943	Same		
59 Shark, man-eater ⁶ (<i>Carcharodon carcharias</i>)	2372		181	117	Streaky Bay, Australia	1953	Same		
60 Shark, porbeagle (<i>Lamna nasus</i>)	260		136	68½	Durban, S. Africa	1949	Same		
61 Shark, thresher (<i>Alopias vulpinus</i>)	922				Bay of Islands, N. Z.	1937	Same		
62 Shark, tiger (<i>Galeocerdo cuvier</i>)	1382		166	93	Sydney Heads, Australia	1939	Same		
63 Snook ⁷ (<i>Centropomus undecimalis</i>)	50	8	55		Gatun Spillway, C. Z.	1944	Same		
64 Swordfish (<i>Xiphias gladius</i>)	1182		179	78	Iquique, Chile	1953	Same		
65 Tarpon (<i>Tarpon atlanticus</i>)	247		89½		Panuco River, Mexico	1938	350		Hillsboro River, Fla.
66 Tuna, Allison ⁸ (<i>Thunnus albacares</i>)	265		73	53	Makua, T. H.	1937	Same		
67 Tuna, big-eyed (<i>Parathunnus sibi</i>)	368		89	63½	Cabo Blanco, Peru	1953	Same		
68 Tuna, bluefin (<i>Thunnus thynnus</i>)	977		116	94½	St. Ann Bay, N. S.	1950	1800		Wedgeport, Nova Sco.
69 Tuna, dog-toothed (<i>Gymnosarda nuda</i>)	151	8			Tahiti	1936	Same		
70 Wahoo (<i>Acanthocybium solandri</i>)	133	8	83	31	Green Cay, Bahamas	1943	Same		
71 Weakfish (<i>Cynoscion regalis</i>)	17	8	46	19	Mullica River, N. J.	1944	30		New Jersey
72 Weakfish, spotted (<i>C. nebulosus</i>)	15	3	34½	20½	Fort Pierce, Fla.	1949	15	4	Indian River, Fla.
73 Yellowtail (<i>Seriola dorsalis</i>)	90		59	35½	La Paz, Mexico	1948	Same		

/1/ Compiled by Field and Stream magazine. /2/ Or steelhead. /3/ Compiled by International Game Fish Association. /4/ Northern fluke. /5/ Or king mackerel. /6/ Or white shark. /7/ Robalo. /8/ Or yellowfin.

135. BODY WEIGHTS: INSECTS

Except where otherwise indicated, values are as follows: those for larvae are for the last instar; averages for both sexes are in milligrams; and ranges in parenthesis conform with estimate "c" of the 95% range (cf Introduction).

Species	Fresh Weight			Dry Weight		
	Larva mg	Pupa mg	Adult mg	Larva mg	Pupa mg	Adult mg
ORTHOPTERA						
1 Cockroach, American (<i>Periplaneta americana</i>)			♂890(550-1470); ♀1050(650-1720)			
2 Cockroach, giant (<i>Micropanesthia rhinoceros</i>)			19.3g (18.4-19.5g)			
3 Cockroach, German (<i>Blattella germanica</i>)			♂(39-45); ♀(70-73)			
4 Cockroach, Hawaiian (<i>Nyctobora noctivaga</i>)			(1290-2190)			
5 Cockroach, Oriental (<i>Blatta orientalis</i>)			♂400(323-515) ¹ ; ♀750(540-870) ^{1,2}			♂100(81-126) ¹ ; ♀205(147-237) ¹
6 Grasshopper, differential (<i>Melanoplus differentialis</i>)			♂854(436-1232); ♀1428(812-2607)			
7 Grasshopper, Rocky Mt. (<i>M. mexicanus mexicanus</i>)			♂(153-161) ³ ; ♀(156-165) ³			
8 Locust, migratory (<i>Locusta migratoria</i>)	(372-578) ⁴		♂1350(1200-1400); ♀2500(2250-2900) ⁵	119-183 ⁶		♂565 ⁷ ; ♀1212 ^{8,9}
9 Walking stick (<i>Dixippus morosus</i>)			1050(900-1100)			
10 Walking stick (<i>Sphodromantis bioculata</i>)			2079			
ODONATA						
11 Fly, big green dragon (<i>Anax junius</i>)	(1200-1500)		(500-900)			
ANOPLURA						
12 Louse, bloodsucking (<i>Enderleinellus zonatus</i>)			♂0.005 ¹⁰			
HEMIPTERA						
13 Bug, boxelder (<i>Leptocoris trivittatus</i>)			(32-39) ³			(10.5-10.6) ³
14 Bug, milkweed, large (<i>Oncopeltus fasciatus</i>)			♂47(31-75); ♀66(40-95)			
LEPIDOPTERA						
15 Cabbageworm, imported (<i>Pieris rapae</i>)	156(110-165)					
16 Hornworm, tomato (<i>Protoparce quinquemaculata</i>)	8.3g (6.2-10.5g)					
17 Moth, bee (<i>Galleria mellonella</i>)	175(85-310)			64(30-110)		
18 Moth, codling (<i>Carpocapsa pomonella</i>)	47(42-63)					
19 Moth, raisin (<i>Ephestia figulilella</i>)	19.4					
20 Moth, striped sphinx (<i>Deilephila euphorbiae</i>)	4038	2609	1263	848	652	401
21 Moth, webbing clothes (<i>Tineola biselliella</i>)	(4.9-9.2) ¹¹	(3.0-5.5) ¹¹	♂(2.1-4.3); ♀(4.1-9.4) ¹¹			
22 Silkworm (<i>Bombyx mori</i>)	1770 ¹²	1170		374	339	
DIPTERA						
23 Fly, black blow (<i>Phormia regina</i>)	44(22-63)		♂(38-40) ³ ; ♀(42-50) ³	9(5-13)		
24 Fly, black cherry fruit (<i>Rhagoletis fausta</i>)			♂3.0(1.8-3.9) ¹³ ; ♀4.1(1.5-6.8) ^b			
25 Fly, bluebottle (<i>Calliphora erythrocephala</i>)			♂(50-69) ³ ; ♀(60-77) ³			
26 Fly, giant crane (<i>Tipula abdominalis</i>)	1200(800-1600)					
27 Fly, greenbottle (<i>Lucilia sericata</i>)	0.05 ¹³	28(24-35)	♂27; ♀40			
28 Fly, house (<i>Musca domestica</i>)		(22-27) ¹⁴	♂(12-17); ♀(16-21)			
29 Maggot, apple (<i>Rhagoletis pomonella</i>)			♂4.6(2.6-7.5) ¹³ ; ♀6.9(1.7-11) ^b			
30 Maggot, cherry (<i>R. cingulata</i>)			♂3.8(2.4-5.2) ¹³ ; ♀5.1(3.2-7.0) ^b			
31 Mosquito (<i>Culex tarsalis</i>)		2.2				
32 Mosquito, malaria (<i>Anopheles quadrimaculatus</i>)	1.91	♂2.99; ♀3.45	♂1.37; ♀1.66 ¹⁵	0.61	♂0.60; ♀0.69	♂0.39; ♀0.47
33 Mosquito, yellow-fever (<i>Aedes aegypti</i>)			(3.6-3.9) ¹⁶			
COLEOPTERA						
34 Beetle, Colorado potato (<i>Leptinotarsa decemlineata</i>)	98(83-110) ¹⁷		♂160(146-176); ♀173			53
35 Beetle, confused-flour (<i>Tribolium confusum</i>)	2.0(1.5-2.4)		2.1(1.4-3.5) ¹⁸			0.7(0.6-0.8) ¹⁹
36 Beetle, convergent lady (<i>Hippodamia convergens</i>)			21.3			10.4
37 Beetle, diving (<i>Dysticus marginalis</i>)	1366(1305-1498)	1950	1356(1186-1466)			
38 Beetle, goliath (<i>Goliathus goliathus</i>) ²⁰			(40-100g) ²¹			(15-35g)
39 Beetle, Japanese (<i>Popillia japonica</i>)	(196-276)	(176-222) ³	♂114; ♀146	(44-60) ³	(42-52) ³	♂38; ♀49
40 Beetle, lady (<i>Ceratomegilla fuscilabrus</i>)			13.1			5.4
41 Mealworm, yellow (<i>Tenebrio molitor</i>)	(83-180) ²²					33(22-46)
42 Weevil, bean (<i>Acanthoscelides obtectus</i>)			♂(2.9-6.8); ♀(2.8-8.3)			
HYMENOPTERA						
43 Ant, giant (<i>Camponotus gigas</i>)			(75-347)			
44 Bee, honey, worker (<i>Apis mellifera</i>)	137(158-171)	150(147-176)	120(87-134) ²³	35(34-41)		(16-18.6) ³
45 Wasp, paper-nest (<i>Polistes variatus</i>), queen			149			59
46 Wasp, parasitic (<i>Caraphraetis cinctus</i>)			0.005 ^{10,24}			

/1/ Five da adult. /2/ 60-70 da, ♀1036(833-1165); 120 da, ♀914(781-1200). /3/ Averages from different experiments. /4/ At fifth instar; first instar, 14.3; second, 33.2-37.6; third, 66.4-77.4; fourth, 164-221. /5/ One da, ♀960-1900. /6/ At fifth instar; first instar, 3.12; second, 6.2-7.3; third, 16.2-26.6; fourth, 41.5-83.4. /7/ One da, ♂202-233. /8/ One da, ♂284-346. Values in Footnotes 4-8 are averages from different phases and rearing conditions. /9/ Weight prior to laying eggs. /10/ Smallest known insects; weights are approximate calculations from published measurements. /11/ Smaller if reared at 30°C; larger at 20°C. /12/ Other values, 3500; Italian strain, 4100; Japanese strain, 8417. /13/ Value for one hr larvae; 24 hr, 1.5(1-2); 48 hr, 17.8(16-20); 72 hr, 52(45-57); 96 hr, 52(43-56); 144 hr, 42(39-44). /14/ Also reported as (16-24.3); densely crowded cultures give pupae as small as 4 mg. /15/ Unfed ♀. /16/ Unfed, 1.5-1.75. /17/ Age not stated; probably only partly grown. /18/ One da adult, fresh weight 1.75(1.5-2.0). /19/ One da adult. /20/ Heaviest known insect. /21/ Calculated from dry weight of museum specimens corrected for recorded measurements. /22/ From hatching to largest fully grown larvae, 1-200. /23/ Queen, 262. /24/ Egg, 0.0002.

136. TOOTH DEVELOPMENT: MAMMALS

Part I: AGES OF TOOTH DEVELOPMENT AND ERUPTION: MAN
Values are approximate averages for whites without regard to sex.
F = fetal age; P = postnatal age.

Teeth	Appearance of Tooth Bud		Beginning of Calcification	
	Deciduous	Permanent	Deciduous	Permanent
	mo	mo	mo	mo
1 Incisors, first	F 3	F 6	F 5	P 3.5
2 second	F 3	F 6	F 5	P 3.5, 12 ¹
3 Canines	F 3	F 6	F 6	P 4.5
4 Premolars, first		P 10		P 21
5 second		P 18		P 30
6 Molars, first	F 3	F 5	F 5	Birth
7 second	F 3	P 6	F 6	P 33
8 third		P 60		P 7-10 yr
Teeth	Emergence into Oral Cavity		Root Completion	
	Deciduous	Permanent	Deciduous	Permanent
	mo	yr	yr	yr
9 Incisors, first	P 7.79, 4 ^{1,2}	P 6, 7 ¹	P 1.5-2	P 9-10
10 second	P 12	P 8	P 1.5-2	P 10-11
11 Canines	P 20	P 10, 11 ¹	P 2.5-3	P 12-15
12 Premolars, first		P 10		P 12-13
13 second		P 11		P 12-14
14 Molars, first	P 16	P 6	P 2-2.5	P 9-10
15 second	P 27 ³	P 12	P 3	P 14-16
16 third		P 20.5		P 18-25

/1/ First value mandibular, second value maxillary tooth. /2/ 4-12 mo = 98% range; 0-16 mo = extreme range. Prenatal emergence occurs rarely. /3/ 18-36 mo = 98% range; 10-38 mo = extreme range.

Part II: AGES OF DECIDUOUS TOOTH ERUPTION: MAMMALS

Values are days. Ranges in parentheses, conforming to estimate "b" or "c" of the 95% range (cf Introduction), are noted by superscript. MX = maxillary; MD = mandibular.

Animals		Incisors			Canines	Molars		
		First	Second	Third		First	Second	Third
1 Man	♂	MX 277(187-367) ^b	316(173-459) ^b		575(414-736) ^b	486(349-623) ^b	839(576-1102) ^b	
2		MD 222(126-318) ^b	395(228-562) ^b		587(415-759) ^b	492(378-606) ^b	787(560-1014) ^b	
3	♀	MX 292(172-412) ^b	362(201-523) ^b		611(421-801) ^b	477(340-614) ^b	863(606-1120) ^b	
4		MD 237(112-362) ^b	420(206-634) ^b		614(412-816) ^b	474(343-605) ^b	824(573-1075) ^b	
5 Cattle ¹		MX [0-7] ²	(0-14) ²	(0-21) ²	(14-42) ³	(0-14) ²	(0-10) ²	(0-10) ²
6		MD [0-7] ²	(0-14) ²			(0-14) ²	(0-10) ²	(0-10) ²
7 Chimpanzee ⁴	♂	MX 111(77-161) ^c	122(83-177) ^c		355(266-411) ^c	126(77-180) ^c	308(226-446) ^c	
8		MD 95(55-126) ^c	124(68-188) ^c		376(293-459) ^c	150(79-210) ^c	247(183-338) ^c	
9	♀	MX 76(40-108) ^c	94(74-112) ^c		327(226-445) ^c	111(74-152) ^c	290(243-379) ^c	
10		MD 70(53-83) ^c	88(65-112) ^c		351(265-492) ^c	135(106-176) ^c	225(154-291) ^c	
11 Dog ¹		MX (21-42)	(21-42)	(28-42)	(21-28)	(21-35)	(21-35)	(21-28)
12		MD (21-42)	(21-42)	(28-42)	(21-28)	(21-35)	(21-35)	(21-28)
13 Horse ¹		MX (0-14) ²	(14-42)	(150-270)	Vestigial ⁵	(0-14) ²	(0-14) ²	(0-14) ²
14		MD (0-14) ²	(14-42)	(150-270)	Vestigial ⁵	(0-14) ²	(0-14) ²	(0-14) ²
15 Monkey, rhesus	♂	MX 19.1(0.3-36) ^b	39(15-63) ^b		68(41-95) ^b	73(49-97) ^b	164(117-211) ^b	
16		MD 15.2(0.3-34) ^b	23(1-45) ^b		71(44-98) ^b	78(54-102) ^b	152(115-189) ^b	
17	♀	MX 19.5(0.7-38) ^b	38(14-62) ^b		71(44-98) ^b	68(41-95) ^b	155(110-200) ^b	
18		MD 16(0.5-32) ^b	23(3-43) ^b		73(42-104) ^b	73(48-98) ^b	139(102-176) ^b	
19 Orangutan ⁷	♂	MX 147	229		343	169	303	
20		MD 134	204		349	162	283	
21 Pig ¹		MX (14-28)	(60-90)	Prenatal	Prenatal	(35-49)	(4-8)	(4-8)
22		MD (14-28)	(45-60)	Prenatal	Prenatal	(35-49)	(14-8)	(14-28)

/1/ Values vary with breed. /2/ Lower limit of range prenatal in many animals. /3/ Fourth incisor. /4/ Similar values for lowland gorilla (Gorilla gorilla) with possible exception that canines may precede second molars. /5/ Vestigial teeth; do not erupt. /6/ Prenatal eruption. /7/ Values from single animal.

Part III: AGES OF PERMANENT TOOTH ERUPTION: MAMMALS

Values are years unless otherwise indicated. Ranges in parentheses for white male and female are estimate "b," and for monkey estimate "c," of the 95% range (cf Introduction). MX = maxillary; MD = mandibular.

Animals		Incisors			Canines	Premolars				Molars		
		First	Second	Third		First	Second	Third	Fourth	First	Second	Third
1 Man, white,	MX	7.47(5.88-9.06)	8.67(6.75-10.59)		11.69(9.0-14.38)	10.40(7.52-13.28)	11.18(8.1-14.26)			6.40(4.83-7.97)	12.68(9.99-15.37)	20.5(16-27) ¹
2 male	MD	6.54(5.01-8.07)	7.70(5.98-9.42)		10.79(8.3-13.28)	10.82(7.94-13.7)	11.47(8.18-14.76)			6.21(4.64-7.78)	12.12(9.45-14.79)	20.5(16-27) ¹
3 female	MX	7.20(5.61-8.79)	8.20(6.28-10.12)		10.98(8.29-13.67)	10.03(7.15-12.91)	10.88(7.8-13.96)			6.22(4.65-7.79)	12.27(9.58-14.96)	20.5(16-27) ¹
4	MD	6.26(4.73-7.79)	7.34(5.62-9.06)		9.86(7.37-12.35)	10.18(7.3-13.06)	10.89(7.6-14.18)			5.94(4.37-7.51)	11.66(8.99-14.33)	20.5(16-27) ¹
5 Negro ²	MX	6.0(5.0-8.0)	7.5(5.0-8.0)		10.3(8.0-13.0)	10.0(8.0-12.0)	10.3(8.0-12.0)			6.0(5.0-8.0)	11.5(9.0-13.0)	19.0(12-?)
6	MD	5.5(5.0-7.0)	6.5(5.0-8.0)		10.0(6.0-13.0)	10.0(8.0-13.0)	10.3(8.0-13.0)			5.5(5.0-8.0)	11.5(9.0-14.0)	18.0(12-?)
7 Cattle ³	MX					(2.0-2.5)	(1.5-2.5)	(2.5-3.0)		(0.4-0.7)	(1.0-1.5)	(2.0-2.5)
8	MD	(1.5-2.0)	(2.0-2.5)	(2.8-3.3)	(3.5-4.0) ⁴	(2.0-2.5)	(1.5-2.5)	(2.5-3.0)		(0.4-0.7)	(1.0-1.5)	(2.0-2.5)
9 Chimpanzee ⁵	MX	5.4(4.8-6.0)	5.8(5.3-6.2)		7.2(6.8-7.5)	6.2(5.8-6.6)	6.6(6.0-7.2)			2.9(2.8-3.0)	6.4(6.1-6.8)	10.3(9.8-11.2)
10	MD	5.2(4.8-5.8)	5.5(5.4-6.1)		7.5(7.0-8.3)	6.0(4.8-6.7)	6.5(6.1-7.0)			2.9(2.8-3.0)	6.3(6.1-6.6)	9.3(8.7-10.1)
11 Dog ³	MX	(0.2-0.4)	(0.2-0.4)	(0.2-0.4)	(0.3-0.5)	(0.3-0.5)	(0.4-0.5)	(0.4-0.5)	(0.4-0.5)	(0.3-0.5)	(0.4-0.5)	(0.5-0.6)
12	MD	(0.2-0.4)	(0.2-0.4)	(0.3-0.4)	(0.3-0.5)	(0.3-0.5)	(0.4-0.5)	(0.4-0.5)	(0.4-0.5)	(0.3-0.5)	(0.3-0.4)	(0.5-0.6)
13 Goat	MX					(1.0-1.3)	(1.0-1.3)	(1.7-1.8)		20 da	45 da	(0.8-0.9)
14	MD	(1.0-1.3)	(1.7-1.8)	(2.7-3.0)	(3.5-4.0) ⁴	(1.0-1.3)	(1.0-1.3)	(1.7-1.8)		20 da	45 da	(0.8-0.9)
15 Hamster,	MX	(0-2) da								(7-9) da	(13-14) da	(32-36) da
16 golden	MD	(0-2) da								(7-8) da	(12-13) da	(29-32) da
17 Horse ³	MX	(2.2-3.0)	(3.5-4.0)	(4.2-5.0)	(3.5-5.0) ⁶	(0.4-0.5)	(2.0-2.5)	(3.0-3.5)	(4.0-4.5)	(0.5-1.0)	(1.5-2.2)	(3.5-4.5)
18	MD	(2.2-3.0)	(3.5-4.0)	(4.2-5.0)	(3.5-5.0)	(0.4-0.5) ⁷	(2.0-2.5)	(2.5-3.0)	(3.5-4.0)	(0.5-1.0)	(1.5-2.2)	(3.5-4.5)
19 Monkey, rhesus	MX	2.7(2.1-3.0)	3.2(3.1-3.4)		4.3(3.8-5.4)	3.9(3.5-4.8)	4.0(3.6-4.7)			1.5(1.2-1.9)	3.6(3.2-4.0)	6.1(4.9-10.9)
20	MD	2.8(2.2-3.0)	3.0(2.7-3.4)		4.2(3.7-5.2)	4.2(3.7-5.1)	4.1(3.6-4.9)			1.3(1.0-1.9)	3.5(3.2-4.2)	5.7(4.7-7.6)
21 Mouse, albino	MX	10 da								15 da	(15-20) da	28 da
22	MD	10 da								15 da	(15-20) da	28 da
23 Pig ³	MX	1.0	(1.3-1.7)	(0.7-0.8)	(0.7-0.8)	0.4	(1.0-1.3)	(1.0-1.3)	(1.0-1.3)	(0.3-0.5)	(0.7-1.0)	(1.5-1.7)
24	MD	1.0	(1.3-1.7)	(0.7-0.8)	(0.7-0.8)	0.4	(1.0-1.3)	(1.0-1.3)	(1.0-1.3)	(0.3-0.5)	(0.7-1.0)	(1.5-1.7)
25 Rat, albino	MX	(8-10) da								20 da	(22-23) da	(31-36) da
26	MD	(8-10) da								19 da	(21-22) da	(29-35) da
27 cotton	MX	(Prenatal-1.0) da								(5-7) da	(28-33) da	(26-30) da
28	MD	Prenatal								(4-7) da	(7-12) da	(26-30) da
29 Sheep	MX					(1.5-2.0)	(1.5-2.0)	(1.5-2.0)		0.4	(0.7-1.0)	(1.5-2.0)
30	MD	(1.0-1.5)	(1.5-2.0)	(2.5-3.0)	(3.5-4.0) ⁴	(1.5-2.0)	(1.5-2.0)	(1.5-2.0)		0.3	(0.7-1.0)	(1.5-2.0)

/1/ Eruption at 13 years rare; somewhat less exceptional at ages 14 and 15. /2/ African Zulus. /3/ Values vary with breed. /4/ Fourth incisor. /5/ Values derived from 3-6 animals of closely estimated ages. Gorilla data available only for individuals captured at very early age; values are approximately the same as for the chimpanzee. /6/ Usually absent in mares. /7/ Rarely erupts.

Dist. = distally; extr. = extremities; f. = fused; innom. = innominate; pn. = prenasal;

Bone	Monotremata		Marsu- pialia	Insec- tivora	Chi- roptera	Primates				
	Platypus, duckbilled ("Platypus ornitho- rhynchus")	Anteater, spiny (Tachyglossus spp)	Opossum, Virginia (Didelphis virginiana)	Shrew, common (Sorex personatus)	Bat, big brown (Eptesicus fuscus)	Lemur (Lemur macaco)	Monkey, New World "Howler" (Alouatta balzabul)	Monkey, Old World "Guereza" (Colobus polykomos)	Chimpanzee (Pan troglodytes)	Man (Homo sapiens)
Skull										
1 Occipital (chondral)	1	1	1	1	1	1	1	1	1	1
2 Parietal (dermal)	1 pr., f.	1 pr., f.	1 pr.	1 pr., f.	1 pr., f.	1 pr.	1 pr., f.	1 pr., f.	1 pr.	1 pr.
3 Sphenoid ²										
4 Ethmoid (chondral)	1	1	1	1	1	1	1	1	1	1
5 Turbinal (chondral)	2 pr.	2 pr.	2 pr.	2 pr.	2 pr.	2 pr.	2 pr.	2 pr.	2 pr.	1 pr.
6 Interparietal (dermal)	0	0	0	0	0	0	0	0	0	0
7 Frontal (dermal)	1 pr., f.	1 pr., f.	1 pr., f.	1 pr.	1 pr.	1 pr.	1 pr., f.	1 pr., f.	1 pr., f.	1 pr., f.
8 Nasal (dermal)	1 pr., 1 pn.	1 pr., f.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr., f.	1 pr., f.	1 pr.
9 Lacrimal (dermal)	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.
10 Temporal, periotic ³ (petrosal)	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.
11 Temporal, tympanic	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	f.	f.	f.	f.	f.
12 Temporal, squamosal (dermal)	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	0	1 pr.	1 pr., f.	1 pr., f.	1 pr., f.
13 Premaxilla (dermal)	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.
14 Maxilla (dermal)	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.
15 Jugal (zygomatic, or malar; dermal)	1 pr.	1 pr.	1 pr.	0	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.
16 Vomer (chondral)	1	1	1	1	1	1	1	1	1	1
17 Palatine (dermal)	1 pr., f.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.
18 Mandible (dermal)	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr., f.	1 pr., f.	1 pr., f.	1 pr., f.	1 pr., f.
19 Hyoid, basi- (splanchnic)	1	1	1	1	1	1	1	1	1	1
20 Hyoid, stylo- (splanchnic)	0	0	0	1 pr.	1 pr.	1 pr.	0	0	0	0
21 Hyoid, epi- (splanchnic)	1 pr.	1 pr.	0	1 pr.	1 pr.	1 pr.	0	0	0	0
22 Hyoid, cerato- (splanchnic)	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	0	0	1 pr.
23 Hyoid, thyro- (splanchnic)	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.
Vertebrae										
24 Cervical	7	7	7	7	7	7	7	7	7	7
25 Thoracic	17	16	13	13	11-12	12	12-13	12-13	13	12
26 Lumbar	2	3	6	6	5-6	6	6	6	4	5
27 Sacral	2	3-4	2	3	3	3	3	3	4-5	5, f.
28 Caudal	20-23	12-13	19-35	9*	25-29	27*	23*	4-5	4	4
Vertebral Ribs										
29 Ribs, "true"	6 pr.	6 pr.	7 pr.	13 pr.	7 pr.	5 pr.	7 pr.	7 pr.	7 pr.	7 pr.
30 Ribs, "false"	11 pr.	10 pr.	6 pr.		4 pr.	5 pr.	7-8 pr.	5-6 pr.	6 pr.	5 pr.
Sternum										
31 Manubrium	1	1	1	1	1	1	1	1	1	1
32 Sternebrae	3	3, f.	4	5	1	4	4	4	1	1
33 Xiphisternum	0	1	1	1	f.	1	1	1	1	1
34 Ribs, sternal	6 pr.	6 pr.	7 pr.	7 pr.	7 pr.	1	1	1	1	1
Pectoral Girdle										
35 Interclavicle	1	1	0	0	0	0	0	0	0	0
36 Coracoid	1 pr.	1 pr.	*	*	*	*	*	*	*	*
37 Coracoid, anterior	1 pr.	1 pr.	0	0	0	0	0	0	0	0
38 Clavicle	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.
39 Scapula	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.	1 pr.
Upper Extremity										
40 Humerus	1	1	1	1	1	1	1	1	1	1
41 Radius	1	1	1	1	1	1	1	1	1	1
42 Ulna	1	1	1	1	* or 0	1	1	1	1	1
43 Carpus										
44 Scaphoid	1	1	1	1	1	1	1	1	1	1
45 Lunate	1	1	1	1	1	1	1	1	1	1
46 Cuneiform ³ (triquetral)	1	1	1	1	1	1	1	1	1	1
47 Pisiform	1	1	1	1	1	1	1	1	1	1
48 Centrale	0	0	0	0	0	0	0	0	0	0
49 Trapezium	1	1	1	1	1	1	1	1	1	1
50 Trapezoid	1	1	1	1	1	1	1	1	1	1
51 Magnum ³ (capitate)	1	1	1	1	1	1	1	1	1	1
52 Unciform ³ (hamate)	1	1	1	1	1	1	1	1	1	1
53 Metacarpus	5	5	5	5	5	5	5	5	5	5
54 First										
55 Second										
56 Third										
57 Fourth										
58 Fifth										
Phalanges										
59 First digit	2	2	2	2	2	2	2	2	2	2
60 Second digit	3	3	3	3	2	3	3	3	3	3
61 Third digit	3	3	3	3	3	3	3	3	3	3
62 Fourth digit	3	3	3	3	2	3	3	3	3	3
63 Fifth digit	3	3	3	3	2	3	3	3	3	3

/1/ The order Edentata is so diversified that all skeletal modifications cannot be included. /2/ In most mammals the sphenoid element is formed anatomy; alternate name, used in human anatomy (Nomina Anatomica, 1955), is in parentheses. /4/ Fused with sphenoid. /5/ Ossified

pr. = pair; prox. = proximally; sph. = sphenoid; var. = variable; * = rudimentary bone.

by union of basisphenoid, presphenoid, alisphenoids, orbitosphenoids, pterygoids, and possibly other skull bones. /3/ Name used in mammalian intermediate ribs are present at the ventral ends of each of the first 6 pairs of vertebral ribs.

137. NUMBER OF BONES:

Dist. = distally; extr. = extremities; f. = fused; innom. = innominate; pn. = prenasal;

Bone	Monotremata		Marsu- pialia	Insec- tivora	Chi- roptera	Primates				
	Platypus, duckbilled (Platypus ornitho- rhynchus)	Anteater, spiny (Tachyglossus spp)	Opossum, Virginia (Didelphis virginiana)	Shrew, common (Sorex personatus)	Bat, big brown (Eptesicus fuscus)	Lemur (Lemur macaco)	Monkey, New World "Howler" (Alouatta balzabul)	Monkey, Old World "Guereza" (Colobus polykomos)	Chimpanzee (Pan troglodytes)	Man (Homo sapiens)
Pelvic Girdle										
64 Epipubic	1 pr.	1 pr.	1 pr.	0	0	0	0	0	0	0
65 Ilium	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.	1 pr., innom.
66 Ischium										
67 Pubis										
Lower Extremity										
68 Femur	1	1	1	1	1	1	1	1	1	1
69 Patella	1	1	0	1	1	1	1	1	1	1
70 Tibia	1	1	1	1	1	1	1	1	1	1
71 Fibula	1	1	1	1	1	1	1	1	1	1
Tarsus										
72 Astragalus ³ (talus)	1	1	1	1	1	1	1	1	1	1
73 Calcaneus	1	1	1	1	1	1	1	1	1	1
74 Navicular	1	1	1	1	1	1	1	1	1	1
75 Cuneiform, medial	1	1	1	1	1	1	1	1	1	1
76 Cuneiform, intermediate	1	1	1	1	1	1	1	1	1	1
77 Cuneiform, lateral	1	1	1	1	1	1	1	1	1	1
78 Cuboid	1	1	1	1	1	1	1	1	1	1
79 Metatarsus	5	5	5	5	5	5	5	5	5	5
80 First										
81 Second										
82 Third										
83 Fourth										
84 Fifth										
Phalanges										
85 First digit	2	2	2	2	2	2	2	2	2	2
86 Second digit	3	3	3	3	3	3	3	3	3	3
87 Third digit	3	3	3	3	3	3	3	3	3	3
88 Fourth digit	3	3	3	3	3	3	3	3	3	3
89 Fifth digit	3	3	3	3	3	3	3	3	3	3

/1/ The order Edentata is so diversified that all skeletal modifications cannot be included. /2/ P. phocaena has 5 digits: the first is rudimentary name, used in human anatomy (Nomina Anatomica, 1955), is in parentheses.

138. BONE: SOME

Values in parentheses are estimates "b" and "c" of the 95% range

Compressive Strength: a measure of the load or force per unit area required to crush a body. **Tensile Strength:** a measure of the load or force per unit area required to produce torsion or twisting of a body. This is also called Young's modulus. **Specific Gravity:** a ratio of the weight of a volume of material to the weight of the same volume of water.

Part I: MAN

Specimen Type, Condition and Loading ¹		Value	Specimen Type, Condition and Loading ¹		Value
Modulus of Elasticity		kg/sq mm (x 1000)	Tensile Strength		kg/sq mm
Tension			18 Compact, fresh		9.97(5.74-11.00) ^c
1 Compact, fresh		2.31(1.82-2.71) ^c	19 Compact, dry		11.48(10.02-15.27) ^c
2 Compact, embalmed wet		1.60(0.79-2.15) ^c	20 Compact, embalmed wet		8.32(4.81-10.90) ^c
3 Compact, embalmed dry		1.88(1.20-2.58) ^c	21 Compact, embalmed dry		10.78(6.14-15.12) ^c
Compression			Shearing Strength		
4 Compact, embalmed dry		1.94(1.42-2.27) ^c	22 Compact, fresh, parallel		5.03(4.25-6.50) ^c
Bending			23 Compact, fresh, perpendicular		11.85(10.50-12.99) ^c
5 Compact, fresh		2.21(1.89-2.47) ^c	24 Compact, embalmed wet, perpendicular		6.89(4.23-10.76) ^c
6 Compact, dry		2.29(1.96-2.45) ^c	25 Compact, embalmed dry, perpendicular		5.62(2.52-8.87) ^c
Compressive Strength		kg/sq mm	26 Spongy, fresh, parallel ²		0.20(0.14-0.29) ^c
7 Compact, fresh, parallel		14.74(11.37-19.37) ^c	27 Spongy, fresh, perpendicular ²		0.56(0.45-0.62) ^c
8 Compact, dry, parallel		17.37(11.25-23.19) ^c	Torsion Strength		
9 Compact, embalmed wet, parallel		13.36(9.00-17.72) ^b	28 Compact, fresh		7.9(7.097-9.31) ^c
10 Compact, embalmed wet, perpendicular		14.35(9.996-18.39) ^c	29 Compact, embalmed dry		7.47(5.87-9.27) ^b
11 Compact, embalmed wet, radially		11.94(5.48-19.40) ^b	Other Properties		
12 Compact, embalmed wet, tangentially		10.78(6.84-14.72) ^b	30 Density, compact, dry, g/cu mm		1.87(1.56-2.07) ^c
13 Compact, embalmed dry, parallel		20.52(16.90-24.14) ^b	31 Hardness ³ , compact, wet		-4.2(-59 to 21) ^c
14 Compact, embalmed dry, perpendicular		16.84(14.63-30.11) ^c	32 Hardness ³ , compact, embalmed wet		16.33(-25 to 38) ^c
15 Compact, embalmed dry, radially		13.50(9.08-17.92) ^b	33 Hardness ³ , compact, embalmed dry		25.20(-24 to 47) ^c
16 Compact, embalmed dry, tangentially		13.11(8.81-17.41) ^b	34 Specific gravity, compact, fresh		1.93(1.80-1.997) ^c
17 Spongy, fresh parallel ²		2.81(1.48-5.09) ^c			

/1/ Specimens loaded as indicated with long axis of bone or fiber. /2/ Specimens punched out from head and neck of femur. /3/ Rockwell factor, 1/8 inch steel ball penetrance, 45 kg load for 10 seconds.

Part II: OTHER ANIMALS

Specimen Type, Condition and Loading ¹		Value	Specimen Type, Condition and Loading ¹		Value
Modulus of Elasticity: Bending		kg/sq mm (x 1000)	Modulus of Elasticity: Bending (concluded)		kg/sq mm (x 1000)
1 Calf, compact, fresh		1.80(1.71-1.89) ^c	5 Swine, domestic, compact, fresh		2.09(1.76-2.41) ^c
2 Fox, compact, fresh		2.24(2.08-2.37) ^c	6 Wolf, compact, fresh		2.24(1.90-2.71) ^c
3 Ox, compact, fresh		2.44(2.13-2.47) ^c	7 Goose, domestic, compact, fresh		1.80(1.68-1.96) ^c
4 Pig, wild, compact, fresh		1.75(1.60-1.90) ^c			

/1/ Specimens loaded as indicated with long axis of bone or fiber.

pr. = pair; prox. = proximally; sph. = sphenoid; var. = variable; * = rudimentary bone.

and cartilaginous, and in the remaining four, varying numbers of phalanges become ossified. /3/ Name used in mammalian anatomy; alternate

(cf Introduction). Data in Part III are presented for purposes of comparison.

Modulus of Elasticity: a number representing the degree of stiffness of a material; obtained by dividing the unit stress by the unit deformation.

Specimen Type, Condition and Loading ¹		Value	Specimen Type, Condition and Loading ¹		Value
Compressive Strength		kg/sq mm	Specific Gravity		
8	Calf, compact, fresh, parallel	12.31(10.92-13.44) ^C	22	Calf, compact, fresh	2.101
9	Ox, compact, fresh, parallel	17.19(12.17-23.42) ^C	23	Cow, compact, fresh	1.980
10	Ox, compact, dry, parallel	15.46(12.87-17.74) ^C	24	Fox, compact, fresh	1.995(1.985-2.006) ^C
11	Ox, compact, fresh, perpendicular	19.81(14.53-23.50) ^C	25	Horse, compact, fresh	1.961(1.924-1.998) ^C
12	Pig, wild, compact, fresh, parallel	13.78(12.92-14.21) ^C	26	Ox, compact, fresh	2.024(1.953-2.024) ^C
13	Swine, domestic, compact, fresh, parallel	13.95(9.996-14.79) ^C	27	Pig, wild, compact, fresh	2.060
14	Wolf, compact, fresh, parallel	19.96(18.69-20.81) ^C	28	Swine, domestic, compact, fresh	1.883(1.802-1.965) ^C
Tensile Strength			29	Swine, suckling, compact, fresh	1.707
15	Calf, compact, fresh, parallel	8.61(5.996-13.32) ^C	30	Wolf, compact, fresh	1.970(1.951-1.984) ^C
16	Ox, compact, fresh, parallel	10.998(9.996-14.99) ^C	31	Chicken, compact, fresh	1.786
17	Ox, compact, dry, parallel	12.43(6.38-16.87) ^C	32	Duck, domestic, compact, fresh	1.840
18	Ox, compact, fresh, perpendicular	9.12(7.77-10.65) ^C	33	Frog, compact, fresh	1.507
19	Pig, wild, compact, fresh, parallel	10.29	Density		g/cu cm
20	Swine, domestic, compact, fresh, parallel	7.30	34	Dog, compact, embalmed dry	1.85(1.59-2.04) ^C
21	Wolf, compact, fresh, parallel	10.77(9.16-12.35) ^C			

21	Wet, compact, fresh, parallel	16.77 (2.16-11.1)
/1/	Specimens loaded as indicated with long axis of bone or fiber.	

Specimen Type and Loading ¹		Value	Specimen Type and Loading ¹		Value	Specimen Type and Loading ¹		Value
Tensile Strength ²		kg/sq mm	Compressive Strength ³ (concluded)		kg/sq mm	Shearing Strength ³ (concluded)		kg/sq mm
1	Conifers, perpendicular	0.2	10	Pine, shortleaf, parallel	4.5	17	Pine, shortleaf	0.8
2	Elm, parallel	20.4				18	Redwood	0.5
3	Fir, Douglas, parallel	8.2	11	Pine, shortleaf, perpendicular	0.6	Tensile Strength		
4	Hardwood, perpendicular	0.6	12	Redwood, parallel	3.6	19	Cast iron, gray iron	10.5-12.7
5	Hickory, parallel	22.5	13	Redwood, perpendicular	0.4	20	Steel, extra soft	31.6-38.7
6	Pine, longleaf, parallel	12.2				21	Wrought iron	29.5-36.6
Compressive Strength ³			Shearing Strength ³			Modulus of Elasticity		kg/sq mm (x 1000)
7	Fir, Douglas, parallel	3.5	14	Fir, Douglas	0.6	22	Cast iron, gray iron	8.4-9.8
8	Pine, Norway, parallel	5.3	15	Pine, longleaf	0.7	23	Steel, extra soft	21.1
9	Pine, Norway, perpendicular	0.6	16	Pine, Norway	0.8	24	Wrought iron	18.3-20.4

/1/ Wood specimens loaded as indicated with fibers. /2/ 15% moisture content. /3/ Small size, air-seasoned.

139. BONE MARROW DIFFERENTIAL CELL COUNT: MAN AND DOG

Values for man based on sternal aspirations, 750 adults, male and female. Values for dog based on rib extrusions, 187 adult dogs. All values are percents and are the grand mean of results of several laboratories using different techniques. Ranges of investigators' means are in parentheses.

Cell Type	Man	Dog	Cell Type	Man	Dog
1 Red	19.1	43.6	14 White, granulocytic (concluded)		
2 Early forms	2.9	5.4	15 Band cells	17.9 (6.1-36.0)	24.6 (11.7-42.0)
3 Proerythroblasts	0.5 (0.2-4.0)	0.5 (0.3-0.6)	16 Segmented cells	15.6 (8.7-27.0)	9.6 (3.9-30.0) ¹
4 Early normoblasts	2.4 (1.5-5.8)	4.9 (1.5-7.8)	17 Eosinophils		3.1 (2.0-4.7)
5 Late forms	16.2	38.2	18 Other	12.6	2.7
6 Intermediate normoblasts	11.7 (5.0-26.4)	22.3 (11.0-26.0)	19 Lymphocytes	9.8 (2.7-24.0)	0.9 (0.7-1.9)
7 Late normoblasts	4.5 (1.6-21.5)	15.9 (4.6-17.4)	20 Monocytes	1.4 (0.7-2.8)	0.2 (0.0-0.2)
8 White	70.0	54.9	21 Megakaryocytes	0.2 (0.03-0.4)	0.4 (0.1-0.6)
9 Granulocytic	57.4	52.2	22 Plasmacytes	0.6 (0.1-1.5)	0.3 (0.0-0.4)
10 Myeloblasts	1.2 (0.3-3.1)	1.2 (0.6-2.4)	23 Reticulum cells	0.6 (0.03-1.6)	0.9 (0.0-1.0)
11 Progranulocytes	3.0 (0.5-4.5)	1.4 (0.7-2.8)	24 Non-identifiable	10.9	1.5
12 Myelocytes	8.7 (0.9-20.3)	4.8 (2.7-8.9)	25 Unclassified cells	1.7 (0.02-3.3)	1.5 (0.0-3.0)
13 Metamyelocytes	11.0 (5.6-22.0)	7.4 (3.4-15.3)	26 Disintegrated cells	9.2 (1.1-20.8)	

/1/ Includes basophils (0.05-0.2).

140. BONE MARROW DIFFERENTIAL CELL COUNT, PREGNANCY: MAN

Values based on 10 ml sternal marrow aspirated from each of 40 pregnant and 28 non-pregnant females. Values and ranges are numbers of cells per cu mm. Because of extreme variability in the "normal" range, averages should be considered with caution. Data adapted from Pitts, H. H., and Packham, E. A., Arch. Int. Med., 64:471-482, 1939.

Cell Type ¹	1st Trimester	2nd Trimester	3rd Trimester	Non-pregnant
	cells/cu mm			
1 Proerythroblasts	56(0-136)	73(0.203)	61(0-210)	28(0-122)
2 Early normoblasts	749(86-1314)	797(251-1875)	1050(51-3937)	616(62-1396)
3 Intermediate normoblasts	1139(259-2628)	1803(314-7000)	1865(51-8636)	1199(134-2904)
4 Late normoblasts	944(28-2700)	835(250-2000)	836(119-2730)	453(43-1089)
5 Myeloblasts	63(0-328)	173(0-1250)	96(0-635)	89(0-279)
6 Programulocytes	378(38-900)	462(69-2500)	341(0-1460)	251(11-736)
7 Early neutrophilic myelocytes	262(0-675)	446(0-3500)	362(51-1050)	147(0-630)
8 Myelocytes, eosinophilic ²	218(28-494)	251(0-1400)	167(0-700)	147(0-544)
9 Myelocytes, neutrophilic	2267(172-4336)	3229(659-13,125)	2138(391-7937)	1568(168-4140)
10 Metamyelocytes, neutrophilic	2165(259-5913)	2623(251-10,250)	1879(340-4900)	1437(168-4324)
11 Band neutrophils	11,659(2,189-28,251)	15,415(3,077-46,250)	11,819(4,901-29,400)	6,048(1,091-14,490)
12 Segmented neutrophils	5445(4050-8835)	5,441(1,575-11,750)	4613(394-8680)	3565(1132-7084)
13 Segmented eosinophils ³	371(48-1140)	299(18-990)	228(0-700)	246(60-642)
14 Segmented basophils	78(0-197)	47(0-125)	49(0-191)	53(0-184)
15 Lymphocytes	3975(2894-6300)	4,467(1,686-10,000)	3719(1318-5400)	3428(1721-6520)
16 Monocytes	333(40-965)	245(0-642)	194(0-732)	312(32-717)
17 Disintegrated cells	4684(1382-8100)	4,675(1,037-11,500)	4,480(1,329-11,900)	3578(1081-6534)
18 Total nucleated cells	34,580(14,400-65,700)	41,510(15,700-125,000)	33,930(16,900-70,000)	23,100(7,500-46,000)

/1/ Proplasmacytes, plasmacytes, basophilic myelocytes, early myelocytes (eosinophilic and basophilic) not tabulated but present in less than 0.1 per cent. /2/ Includes eosinophilic metamyelocytes. /3/ Includes band eosinophils.

141. HISTOCHEMICAL PROPERTIES, BLOOD AND BONE MARROW CELLS: MAN

C = cytoplasm proper; G = specific granules; J = juxtanuclear bodies; M = mitochondria; N = nucleoli.

Cell Type	Lipid ¹	Phospho-lipid ²	Acid Phosphatase ³	Alkaline Phosphatase ³	Ribonucleo-protein ⁴	Carbohydrate ⁵	Peroxidase ⁶
1 Nuclei	Neg	Neg	Pos	Pos ⁷	Pos N	Neg	
2 Cytoplasm							
3 Myeloblasts	Pos M	Pos M	Neg		Pos C ⁸	Neg	Neg
4 Progranulocytes	Pos GM	Pos G ⁷ M	Pos G	Neg ⁹	Pos C ⁸	Neg ^{7,10}	Pos G
5 Myelocytes	Pos GM	Pos G ⁷ M	Pos CG	Neg ⁹	Neg	Pos ^{7,10}	Pos G
6 Metamyelocytes	Pos G ¹¹	Pos G ⁷	Pos G	Pos C ^{8,10}	Neg	Pos ^{7,10}	Pos
7 Segmented neutrophils	Pos G ¹¹	Pos G ⁷	Pos G	Pos C ^{8,10}	Neg	Pos ^{7,10}	Pos
8 Segmented eosinophils	Pos G	Pos G ⁷	Pos G	Neg	Neg	Pos G	Pos
9 Segmented basophils	Pos G	Pos G ⁷	Pos G	Neg	Neg	Pos G ¹⁰	Neg
10 Tissue eosinophils	Pos G	Pos GM	Neg	Neg	Neg	Pos ⁷	Pos
11 Lymphoblasts	Pos M	Pos M			Pos C ⁸		Neg
12 Lymphocytes	Neg	Neg	Pos JG	Neg ¹²	Pos C ⁸	Neg ¹³	Neg
13 Monocytes	Pos GM	Pos G			Pos C	Pos ¹⁰	Pos ¹⁴
14 Megakaryocytes	Pos GM	Pos G ⁷ M	Pos ⁸	Pos C ⁸	Pos C ^{8,9}	Pos ¹⁰	
15 Thrombocytes	Neg	Pos C ⁸ G			Neg	Pos ¹⁰	
16 Proerythroblasts ("rubriblasts")	Pos M	Pos M	Pos J	Neg	Pos C ⁸	Neg	Neg
17 Early normoblasts ("prorubricytes")	Pos M	Pos M	Pos J	Neg	Pos C ⁸	Neg	Neg
18 Intermediate normoblasts ("rubricytes")	Pos M	Pos M			Pos C ⁸	Neg	Neg
19 Late normoblasts ("metarubricytes")	Neg	Neg			Pos C ⁸	Neg	Neg
20 Erythrocytes	Neg	Neg ⁸	Neg ¹⁵	Neg	Neg	Neg	Pos
21 Plasmacytes	Pos G	Pos G ⁶	Pos JG	Pos C ⁸	Pos C	Pos ⁷	Neg
22 Reticulum cells	Pos G	Pos G	Pos G	Pos G	Neg	Pos G ¹⁶	Neg
23 Mast cells	Pos G ¹⁷	Pos G	Pos G	Pos G	Pos CG	Pos CG ¹⁷	Pos

/1/ Stained with Sudan black B unless otherwise specified. /2/ Detected by acid-hematein method; negatively evaluated by pyridine extraction method. /3/ Detected by modified Gomori method using glycerophosphate substrate. /4/ Detected by Feulgen reaction; negatively evaluated by digestion with ribonuclease. /5/ Detected by either periodic acid-Schiff, or by Gomori silver-methenamine methods. /6/ Detected by benzidine-peroxidase. /7/ Controversial. /8/ Diffuse staining. /9/ May be positive (Rabinovitch and Andreucci). /10/ As glycogen. /11/ Stable sudanophilia. /12/ May be positive. /13/ Positive according to Stowell; Wachstein. /14/ Trace. /15/ Positive when substrate is ATP. /16/ Probably is phagocytosed material (Lillie). /17/ Granules positive in many cells, negative in others.

142. COMPARATIVE ANATOMY OF THE HEART: CHORDATES

THE COMPARATIVE ANATOMY OF THE HEART. CHORDATES								
Chordate	Location in Body	Chambers Forming Heart	Atrioventricular Valves	Semilunar Valves	Septum Atriorum	Septum Ventriculorum		
1 Amphioxus	Heart lacking; aortic arches are contractile.							
Fishes	Cervical.	One atrium, one ventricle.	Present, two or more cusps.	Numerous, in series, in conus arteriosus.	None.	None.		
2 Cyclostomes								
3 Selachii								
4 Ganoidii		Two atria, one ventricle.	Lacking but function performed by a fibrocartilaginous swelling.	One set (not in series) in conus arteriosus.	Present.			
5 Teleostei ¹				Numerous in conus; now beginning to divide.				
6 Dipnoi	High in thorax.	Two atria, one ventricle.	Present, right and left cusps.	Present in bulbus cordis.	Perforated.	Incomplete.		
Amphibia		One atrium, one ventricle.						
7 Urodela, with lungs		Two atria, one ventricle.	Present, dorsal and ventral cusps.					
8 Urodela, lungless									One atrium, one ventricle.
9 Anura	High or low in thorax ² .	Two atria, two ventricles.	Two atrioventricular valves.	Present in pulmonary and aortic trunks.	Solid.	Incomplete or complete ³ .		
10 Reptilia								
11 Aves								
12 Mammalia ⁴	Low in thorax.					Complete.		

Chordate		Wall Structure of Chambers	Conus and Truncus Arteriosus	Sinus Venosus Size and Valves	Chambers Containing:			
					Arterial Blood	Mixed Blood	Venous Blood	
1	Amphioxus	Heart lacking; aortic arches are contractile.						
2	Fishes	Atrium generally smooth; ventricles with inner surface netlike or with larger trabeculae.	Conus long and well-developed; truncus represented by ventral aorta.	Sinus venosus large; sino-atrial valve generally well-developed.	None in heart.		Atria and ventricle.	
3	Cyclostomes		Conus long and well-developed; truncus short and little developed.					
4	Selachii		Conus moderately long; truncus long, thin-walled.					
5	Ganoidii		Conus very much reduced; truncus thick-walled and well-developed.					
6	Teleostei ¹		Conus and truncus shortened; bent somewhat spirally; partly or completely separated into two halves.					
7	Dipnoi	Atria smooth; ventricle with many muscle bands transversing cavity, giving it a spongy structure.	Conus incorporating into wall of heart; truncus divided into pulmonary and aortic portions.	Opens into right atrium.	Left atrium.	Ventricle.	Right atrium.	
8	Amphibia		Truncus lacks septum.		Left atrium.	Ventricle.	Right atrium.	
9	Urodela, with lungs		Conus incorporating into wall of heart; truncus divided into pulmonary and aortic portions.	Reduced in size by partial incorporation in right atrial wall; valve persists.	None	None	Atrium, ventricle	
10	Urodela, lungless		Conus incorporating into wall of heart; truncus divided into pulmonary and aortic portions.		Left atrium.	Ventricle.	Right atrium.	
11	Anura	Atria generally smooth; ventricles with trabeculae cordis but ventricular cavities not divided by muscle bands.	Conus entirely incorporated in ventricular mass; truncus directly from ventricles; truncus divided.	Sinus further reduced and valve vestigial.	Left atrium.	Ventricle.	Right atrium.	
12	Reptilia		No conus; truncus completely divided.		Sinus lacking; vestiges of valve are "valvae of the inferior vena cava," "valve of the coronary sinus."	Left atrium and left ventricle.	None.	Right atrium and right ventricle.
13	Aves ⁵							
14	Mammalia ⁴	Atria with moderate ridging (musculi pectinata); ventricles with trabeculae.						

/1/ Teleostei in general. /2/ High in lizards and turtles; low in snakes and crocodiles. /3/ Incomplete in some lizards and snakes; complete in others, e.g., crocodiles. /4/ Mammals in general, including man. /5/ Includes also crocodiles.

143. MALE GENITALIA, DIMENSIONS AND WEIGHT: MAMMALS

Values in parentheses are averages of ranges reported in the literature. L = Length; T = Thickness; W = Width; Wt = Weight.

Species	Testes			Epidi- dymis L, cm	Ductus Deferens L, cm	Seminal Vesicles		Prostate Gland			Bulbourethral Gland		Penis ¹ L, cm
	L, cm	W, cm	T, cm			L, cm	W, cm	L, cm	W, cm	T, cm	L, cm	W, cm	
1 Man (<i>Homo sapiens</i>)	4.2 ²	3.8 ²	2.5 ²	(20-35)	8	(38-61)	4.3	1.7 ⁴	4.0	2.8	1.9	Size of pea	13 ⁵
2 Cat (<i>Felis catus</i>)	1.5	1		2,016								Small ⁶	
3 Cattle (<i>Bos taurus</i>)	11.5	7	6-7	300(284-340)		(25-38)	11.5	5	3.8	1.3	1.3	Very small	91
4 Dog (<i>Canis familiaris</i>)	Relatively small						Absent		Large (variable)			Absent	10
5 Goat (<i>Capra hircus</i>)	10			(255-284)	(40-60)				Disseminate				40
6 Guinea pig (<i>Cavia porcellus</i>)				2.8									
7 Horse (<i>Equus caballus</i>)	11	5	7	(225-300)	(72-86)	(15-20)	17.5	5		2 ⁷		5	2.5
8 Mouse (<i>Mus musculus</i>)							Long, narrow		3 pairs				
9 Rabbit (<i>Oryctolagus cuniculus</i>)	Ellipsoidal			2.6			Single, unpaired		2-lobed with isthmus			Paired, small	4
10 Rat (<i>Rattus rattus</i>)							Long, narrow		2 pairs				
11 Sheep (<i>Ovis aries</i>)	10			(255-284)	(40-60)		5.7	2.5	Disseminate			Relatively large	40
12 Swine (<i>Sus scrofa</i>)				(591-871)	(62-64) ³	(25-30)	14	4.4		2.5 ⁸		12	3 ⁹

/1/ Non-erect. /2/ Age, 20-60 yr. /3/ Extended. /4/ T = 0.9 cm. /5/ Age, 20-25 yr. /6/ Wt = 0.4-0.5 g. /7/ Diameter at isthmus. /8/ Wt = 15-26 g. /9/ Wt = 146-209 g.

144. FEMALE GENITALIA, DIMENSIONS AND WEIGHT: MAMMALS

The size and weight of the ovaries depend on the stage of the ovarian cycle and the number and size of corpora lutea and follicles. Uterine weight is also dependent on the stage of the ovarian cycle as well as age of the animal, size of breed, and virgin or parous condition of the uterus. Values in parentheses are averages of ranges reported in the literature. L = Length; T = Thickness; W = Width; Wt = Weight.

Species	Ovaries				Uterine Tubes L, cm	Total Organ Wt, g	Horns L, cm	Uterus		Cervix		Vagina L, cm	Vulva L, cm
	L, cm	W, cm	T, cm	Wt, g				Body L, cm		L, cm	W, cm		
1 Man (<i>Homo sapiens</i>)	3.5	1.8	1.2	7 ¹	(7-14)	(33-41) ^{2, 3}		8		(2.9-3.4) ²		9 ⁴	
2 Cat (<i>Felis catus</i>)					5		10	2				2	
3 Cattle (<i>Bos taurus</i>)	3.8	2.5		19	(20-23)	700	38	3.8	10	2.5		(25-30)	10
4 Dog (<i>Canis familiaris</i>)		2			(5-7.6)		(11-15)	(2-3)	1			(7.5-15)	
5 Ferret (<i>Mustela putorius</i>)						0.4 ⁵							
6 Goat (<i>Capra hircus</i>)		1.5			(10-15)		(10-12)	2	4			(10-12)	(2.5-3)
7 Guinea pig (<i>Cavia porcellus</i>)					0.3		(5-6)					(2.5-4)	
8 Horse (<i>Equus caballus</i>)	7.5		3.5	(70-80)	(20-30)		25	(18-20)(L);10(W)	(5-8)	3.8		(15-20)	(10-13)
9 Rabbit (<i>Oryctolagus cuniculus</i>)	1.5	0.7	0.6	0.55	10	8	(10-12) ⁶		0.7 ⁶	0.7 ⁶		(3.5-6)	4 ⁷
10 Sheep (<i>Ovis aries</i>)	1.5		1	(4-8) ⁸	(10-15)		(10-12)	2.5	3.8			(7.5-10)	(2.5-3)
11 Swine (<i>Sus scrofa</i>)				(3.5-10)	(15-30)		(120-150)	5	10			(10-13)	7.5

/1/ After pregnancy. /2/ Virgin uterus. /3/ Parous uterus approximately 35 g heavier. /4/ For posterior wall; anterior wall 7 cm. /5/ Anestrus; estrus, 1 g; pseudopregnant, 5 g. /6/ Duplex uterus with two cervices opening into vagina. /7/ At vestibule. /8/ In breeding season, depending on number of ovulations; otherwise smaller.

145. KIDNEY MEASUREMENTS: VERTEBRATES

Species	Body Weight kg	Kidney		Glomerulus				Species	Body Weight kg	Kidney		Glomerulus			
		Weight of One Kidney g	% body wt	Radius μ	Thousands per Kidney ¹	Vol/Kidney cu mm	Vol/g Kidney cu mm			Weight of One Kidney g	% body wt	Radius μ	Thousands per Kidney ¹	Vol/Kidney cu mm	Vol/g Kidney cu mm
1 Man	70	156	0.22	100	1095	4599	29	10 Ox	410	640	0.16	122	3992	29,860	47
2 Cat	2.8	8	0.29	66	184	227	28	11 Rabbit	1.9	6.5	0.34	71	199	300	46
3 Dog	9.1	31	0.34	90	408	1247	40	12 Rat, albino	0.24	0.75	0.31	61	31	30	40
4 Elephant	4545	3650	0.08	169	7510	151,900	42	13 Rat, kangaroo	0.07	0.30	0.43	48	18.8	8.9	30
5 Ground hog	1.2	1.8	0.15	70	96	135	75	14 Swine	47	77	0.16	83	1193	2859	37
6 Guinea pig	0.56	1.9	0.34	63	76	79	42	15 Chicken	2.5				420		
7 Monkey	3.9	9	0.23	83	187	447	50	16 Duck	3.67				994.5		
8 Mouse	0.02	0.12	0.61	37	12.4	2.6	21	17 Goose	5.4				829.5		
9 Opossum	2	5.2	0.26	88	91	256	49	18 Pigeon	0.232-0.420				137-176.5		

/1/ The number of glomeruli per kidney undergoes slow decrease after maturity and as the animal approaches senility.

146. SURFACE AREA RELATIONSHIPS: MAMMALS
Part I: SURFACE AREA FOR KNOWN HEIGHT AND WEIGHT: MAN

Body Weight kg	Height cm																									
	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250	260	
1	5	.18	.20	.23	.26	.29	.33	.37	.42	.48	.55	.62														
2	10		.35	.36	.38	.41	.44	.48	.52	.57	.64	.69	.76													
3	15					.54	.57	.60	.63	.67	.72	.77	.83	.89												
4	20						.68	.72	.76	.80	.85	.91	.97	1.03												
5	25							.80	.84	.88	.93	.98	1.03	1.09	1.15											
6	30								.92	.96	1.01	1.05	1.10	1.16	1.22	1.28										
7	35									1.04	1.08	1.12	1.17	1.23	1.29	1.35	1.42									
8	40									1.11	1.15	1.20	1.25	1.30	1.36	1.42	1.48	1.55								
9	45										1.23	1.27	1.32	1.37	1.43	1.48	1.54	1.61								
10	50										1.30	1.34	1.39	1.44	1.49	1.54	1.60	1.67	1.74							
11	55										1.37	1.42	1.46	1.50	1.55	1.61	1.67	1.73	1.80							
12	60										1.44	1.48	1.52	1.57	1.62	1.67	1.73	1.79	1.85	1.92						
13	65											1.54	1.58	1.63	1.68	1.73	1.79	1.85	1.91	1.97						
14	70											1.61	1.65	1.70	1.75	1.80	1.85	1.91	1.96	2.02	2.08					
15	75											1.68	1.72	1.76	1.81	1.86	1.91	1.96	2.02	2.07	2.13					
16	80											1.74	1.78	1.82	1.86	1.91	1.96	2.02	2.07	2.13	2.18	2.25				
17	85											1.81	1.84	1.88	1.92	1.97	2.02	2.07	2.13	2.18	2.24	2.31				
18	90											1.87	1.90	1.94	1.98	2.03	2.08	2.13	2.18	2.24	2.30	2.36				
19	95												1.97	2.01	2.05	2.09	2.14	2.18	2.24	2.30	2.36	2.42	2.48			
20	100												2.03	2.07	2.12	2.16	2.20	2.24	2.30	2.35	2.41	2.47	2.54			
21	105												2.10	2.14	2.18	2.22	2.26	2.31	2.35	2.41	2.47	2.53	2.60			
22	110												2.17	2.21	2.24	2.28	2.32	2.36	2.41	2.47	2.53	2.58	2.65	2.73		
23	115												2.23	2.27	2.30	2.33	2.38	2.42	2.47	2.53	2.58	2.64	2.71	2.78		
24	120													2.33	2.36	2.39	2.43	2.48	2.53	2.58	2.63	2.70	2.77	2.84	2.93	
25	125													2.39	2.42	2.45	2.49	2.53	2.58	2.63	2.69	2.76	2.83	2.90	2.97	
26	130													2.44	2.47	2.51	2.54	2.59	2.63	2.68	2.75	2.82	2.88	2.95	3.02	
27	135													2.50	2.53	2.56	2.60	2.64	2.69	2.74	2.81	2.87	2.93	3.00	3.08	
28	140													2.55	2.58	2.62	2.66	2.70	2.74	2.80	2.87	2.93	2.98	3.06		
29	145													2.61	2.63	2.67	2.71	2.75	2.80	2.86	2.92	2.98	3.04			
30	150													2.66	2.69	2.73	2.77	2.81	2.86	2.92	2.97	3.03	3.09			
31	155													2.72	2.74	2.78	2.83	2.87	2.92	2.97	3.03	3.08				
32	160													2.77	2.80	2.83	2.88	2.92	2.97	3.02	3.08					
33	165														2.86	2.89	2.93	2.97	3.02	3.07						
34	170														2.91	2.94	2.98	3.03	3.07							
35	175														2.96	2.99	3.03	3.08								
36	180														3.01	3.04	3.08									
37	185														3.06	3.09										

Part II: CONSTANTS FOR ESTIMATING SURFACE AREA: MAMMALS

Ranges in parentheses are estimates "c" and "d" of the 95% range (cf Introduction) for body weight and K-values, respectively. K-values are derived from surface area values taken from extensive literature sources, using the formula $K = A(\text{sq cm})/W^{2/3}(\text{g})$.

Animal	Method ¹	Body Weight g	K-value (Constant)	Animal	Method ¹	Body Weight g	K-value (Constant)
1 Antelope	T	6300	14.1	37 Mouse	S	16.4(10.4-22.0)	11.4(9.7-13.3)
2 Bat	S	64.6(12.7-36.4)	57.5(54.0-59.8)	38 Mouse	S	20.2	6.3
3 Bat	S	83(5-116)	44.5(44.0-45.0)	39 Mouse	M	(16.0-24.8)	9.0(8.4-9.4)
4 Cat	T	1550(1500-1600)	8.7(8.6-8.9)	40 Mouse, deer	S	22.0	8.5
5 Cat ²	S	100(84-116)	10.0(9.9-10.0)	41 Mouse, field	S	29.0(26.0-31.0)	6.9(6.5-7.2)
6 Cat ²	S	708(219-1389)	10.7(9.5-11.9)	42 Mouse, red back	S	22.0	7.1
7 Cattle ²	S	375,000(163,000-641,000)	11.0(9.0-13.8)	43 Opossum	S	1200(1000-1300)	11.3(10.5-11.8)
8 Cattle	S	476,000(208,000-762,000)	9.3(8.1-10.8)	44 Rabbit ⁴	S	32(26-40)	8.5
9 Hereford, thin ²	S	241,000(89,000-407,000)	9.9(9.3-10.5)	45 Rabbit ⁴	S	560(70-925)	9.7
10 Hereford, med ²	S	315,000(78,000-493,000)	9.4(8.8-10.0)	46 Rabbit	T	1130(1120-1140)	10.0(9.0-11.0)
11 Hereford, fat ²	S	314,000(171,000-549,000)	8.6(8.3-9.0)	47 Rabbit	T	2600	5.7
12 Cattle ²	S	695,000(476,000-815,000)	7.6(7.3-7.9)	48 Rat, white	S	25(23-28)	9.5(9.4-9.6)
13 Dog	S	1070(130-3650)	10.1(9.3-11.0)	49 Rat	S	42(35-53)	10.5(10.1-10.8)
14 Dog	S	1080	11.0	50 Rat	S	80(50-129)	9.9(9.6-10.4)
15 Dog	T	9,500(8,900-10,100)	9.9(9.85-9.9)	51 Rat ³	M	95(22-164)	7.6(7.3-8.8)
16 Dog	S & P	12,700(3,200-29,800)	11.6(10.2-12.5)	52 Rat	M	125(24-366)	7.5(6.6-8.3)
17 Dog	M	14,310(3,390-32,640)	11.2(10.3-12.1)	53 Rat	S	133(70-310)	11.6(10.9-12.1)
18 Dog	C	27,000	12.3	54 Rat	S	137(47-295)	9.0
19 Fox	T	6200(6100-6300)	13.0(12.9-13.2)	55 Rat	T	170(164-177)	7.15
20 Goat	T	15,100	10.5	56 Rat	S	176(25-461)	11.4(9.6-13.0)
21 Guinea pig	S	157(123-191)	10.4(10.1-10.8)	57 Rat	M	(19-418)	9.0
22 Guinea pig	S	206(123-269)	9.5(8.4-10.8)	58 Rat	S	(65-335)	10.5
23 Guinea pig	S	256(235-269)	8.6(8.4-8.9)	59 Sheep	T	17,680	11.0
24 Guinea pig ³	S	323(160-810)	8.9(7.9-9.6)	60 Sheep	S	(21,800-29,100)	10.7
25 Guinea pig	S	373(148-650)	9.6(9.0-9.9)	61 Sheep	I	(2,200-68,000)	8.3
26 Guinea pig	T	400(380-420)	7.1	62 Sheep	S	(23,600-37,700)	8.5
27 Hedgehog	S	200	7.5	63 Sheep	S	(3,780-50,400)	9.1
28 Horse	C		9.0	64 Shrew, long-tailed	S	3.5	8.0
29 Horse	S	(47,000-555,000)	10.5	65 Shrew, short-tailed	S	20	7.0
30 Horse	I	(70,000-750,000)	(8.2-10.3)	66 Swine	S		8.8
31 Lion	T	64,200	12.3	67 Swine	T	40,110	15.3
32 Marten, pine	T	1400	8.8	68 Swine	I	(25,000-330,000)	9.0
33 Monkey	M	2670(800-6600)	11.8(10.8-13.2)	69 Swine	S	48,300(1,100-123,000)	9.9(8.6-12.4)
34 Mouse ³	S	12.9	6.9	70 Whale, fin	P	160,000(115,000-220,000)	8.3(7.5-8.9)
35 Mouse	S	14.7(6.0-26.5)	7.9	71 Whale	P	43,000,000	11.1
36 Mouse	S	15.9(10.7-19.7)	10.5(10.4-10.5)	72 Woodchuck	M	1236	9.3

/1/ Method of determining surface area. C = paper cover; I = surface integrator; M = mold method; P = perimeter method; S = skinning; T = triangulation. /2/ "Empty" weight. /3/ Starved animals. /4/ With surface area of one side of ear only.

147. STATURE, WEIGHT, AND SURFACE AREA: MAN, VARIOUS NATIONALITIES AND TYPES

Values in parentheses are ranges and conform with the "b" estimate of the 95% range (cf Introduction).

Race or Nationality		Stature		Weight		Surface Area		Race or Nationality		Stature		Weight		Surface Area
		cm	in	kg	lb	sq m ¹				cm	in	kg	lb	sq m ¹
1 Aeta, Pygmoids (Bataan)	♂	148(138-158)	58(54-62)	42(31-52)	91(69-114)	1.29(1.11-1.47)	17	Chinese (Canton)	♀	148(138-158)	58(54-62)	54(37-71)	119(82-156)	1.43(1.19-1.67)
2 Aeta, Pygmoids (Bataan)	♀	138(131-145)	54(51-57)	37(29-44)	80(65-96)	1.17(1.05-1.29)	18	English, students (Oxford)	♂	178(166-190)	70(65-75)	69(55-83)	151(120-182)	1.82(1.60-2.04)
3 Aeta, Pygmoids (Zambales)	♂	148(139-157)	58(55-62)	40(32-49)	89(70-108)	1.28(1.14-1.42)	19	English, convicts	♂	167(153-181)	66(60-71)	65(50-80)	143(110-177)	1.70(1.45-1.95)
4 Aeta, Pygmoids (Zambales)	♀	138(129-148)	54(51-58)	34(26-42)	75(57-92)	1.14(0.98-1.30)	20	French, workers	♂	169(157-181)	66(62-71)	67(51-83)	147(112-182)	1.73(1.51-1.95)
5 African, Gobaouin (Somaliland)	♂	168(154-183)	66(61-72)	58(44-71)	127(96-157)	1.63(1.39-1.87)	21	French, workers	♀	159(150-168)	62(59-66)	56(42-70)	123(92-155)	1.54(1.34-1.74)
6 African, Gobaouin (Somaliland)	♀	157(148-166)	62(58-65)	60(52-67)	131(114-148)	1.57(1.41-1.73)	22	Indochinese (Cambodja)	♀	149(140-159)	59(55-62)	53(37-68)	116(82-150)	1.44(1.20-1.68)
7 Kung, Bushmen (Kalahari)	♂	157(143-170)	62(56-67)	40(31-50)	89(68-110)	1.33(1.13-1.53)	23	Indochinese (Hué)	♀	146(136-156)	57(53-61)	43(31-54)	94(69-119)	1.28(1.10-1.46)
8 Morocco, natives	♂	169(158-182)	66(62-72)	64(50-78)	140(111-170)	1.71(1.47-1.95)	24	Indochinese (Tonkin)	♂	160(150-170)	63(59-67)	57(49-65)	126(108-144)	1.55(1.35-1.75)
9 Negroes (West Africa)	♂	167(149-186)	66(58-73)	57(42-72)	125(93-158)	1.61(1.34-1.88)	25	Irish (North)	♂	172(160-184)	68(63-72)	68(51-84)	149(112-186)	1.77(1.53-2.01)
10 Tunisia, natives	♂	173(163-183)	68(64-72)	62(53-71)	137(117-156)	1.70(1.56-1.84)	26	Italians	♂	168(155-181)	66(61-71)	63(44-82)	138(97-180)	1.81(1.50-2.12) ²
11 Albanians (South Italy)	♂	164(153-175)	64(60-69)	61(49-73)	135(108-160)	1.64(1.40-1.88)	27	Italians	♀	156(143-170)	61(56-67)	52(34-70)	114(75-154)	1.64(1.31-1.97) ²
12 Americans, white	♂	177(164-191)	70(64-75)	70(55-86)	155(121-189)	1.85(1.61-2.09)	28	Japanese	♂	159(149-170)	63(59-67)	53(38-68)	116(83-150)	1.55(1.31-1.79) ³
13 Americans, white	♀	163(153-173)	64(60-68)	56(40-72)	123(88-158)	1.61(1.34-1.88)	29	Otomi (Mexican Indian)	♂	158(148-167)	62(58-66)	53(43-64)	117(94-140)	1.52(1.34-1.70)
14 Andamanese (Indian Ocean)	♂	148(135-161)	58(53-63)	45(36-54)	98(79-118)	1.35(1.17-1.53)	30	Semang (Malaya)	♂	154(141-167)	60(55-66)	41(29-54)	91(64-118)	1.31(1.13-1.49)
15 Andamanese (Indian Ocean)	♀	138(131-146)	54(51-57)	43(31-55)	94(67-120)	1.24(1.08-1.40)	31	Semang (Malaya)	♀	144(134-154)	57(53-61)	33(24-42)	72(53-91)	1.14(0.96-1.32)
16 Arabs (Yemen)	♂	163(150-175)	64(59-69)	59(48-69)	129(105-153)	1.57(1.41-1.73)	32	Spaniards	♂	169(157-181)	66(62-71)	67(50-84)	147(111-184)	1.74(1.50-1.98)

/1/ Body surface area calculated according to the formula $S = 71.84 \times \text{weight}^{0.425} \times \text{height}^{0.725}$, except where otherwise indicated. /2/ Measured by surface integrator. /3/ Measured by coating method.

148. BODY WEIGHTS WITH ORDINARY CLOTHING: MAN, NORTH AMERICA

Height		Average Body Weights														Desirable Body Weights, >25 yr						
		20-24 yr		25-29 yr		30-34 yr		35-39 yr		40-44 yr		45-49 yr		50-54 yr		55-59 yr		Small Framed	Medium Framed	Large Framed		
cm	in	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	
Male																						
1	149.9	59	53	117	55	122	57	125	58	127	59	130	60	132	60	133	61	134				
2	152.4	60	54	119	56	124	58	127	58	129	60	132	61	134	61	135	62	136				
3	154.9	61	55	121	57	126	59	129	59	131	61	134	62	136	62	137	63	138				
4	157.5	62	56	124	58	128	60	131	60	133	62	136	63	138	63	139	64	140	53-57	116-125	56-60	124-133
5	160.0	63	58	127	59	131	61	134	62	136	63	139	64	141	64	142	65	143	54-58	119-128	58-62	127-136
6	162.6	64	59	131	61	134	62	137	63	140	64	142	65	144	66	145	66	146	55-60	122-132	59-63	130-140
7	165.1	65	61	135	63	138	64	141	65	144	66	146	67	148	68	149	68	150	57-62	126-136	61-65	134-144
8	167.6	66	63	139	64	142	66	145	67	148	68	150	69	152	69	153	70	154	58-63	129-139	62-67	137-147
9	170.2	67	64	142	66	146	68	149	69	152	70	154	71	156	71	157	72	158	60-65	133-143	64-68	141-151
10	172.7	68	66	146	68	150	70	154	71	157	72	159	73	161	73	162	74	163	62-67	136-147	66-71	145-156
11	175.3	69	68	150	70	154	72	158	73	162	74	164	75	166	75	167	77	168	63-68	140-151	68-73	149-160
12	177.8	70	70	154	72	158	74	163	75	167	77	169	78	171	78	172	79	173	65-70	144-155	69-74	153-164
13	180.3	71	72	158	74	163	76	168	78	172	79	175	80	177	81	178	81	179	67-72	148-159	71-76	157-168
14	182.9	72	74	163	77	169	79	174	81	178	82	181	83	183	83	184	83	185	69-74	152-164	73-78	161-173
15	185.4	73	76	168	79	175	82	180	83	184	85	187	86	190	86	191	86	192	71-77	157-169	75-81	166-178
16	188.0	74	78	173	82	181	84	186	86	191	88	194	89	197	89	198	89	199	74-79	163-175	78-83	171-184
17	190.5	75	81	178	85	187	87	192	89	197	91	201	92	204	92	205	93	206	76-82	168-180	80-86	176-189
Female																						
18	149.9	59	51	113	53	116	54	119	55	122	57	126	58	129	59	131	60	132	47-50	104-111	50-53	110-118
19	152.4	60	52	115	54	118	55	121	56	124	58	128	59	131	60	133	61	134	48-51	105-113	51-54	112-120
20	154.9	61	53	117	55	120	56	123	57	126	59	130	60	133	61	135	62	137	49-52	107-115	52-55	114-122
21	157.5	62	54	120	56	122	57	125	58	129	60	133	62	136	63	138	63	140	50-54	110-118	53-57	117-125
22	160.2	63	55	123	57	125	58	128	60	132	62	136	63	139	64	141	64	143	51-55	113-121	54-58	120-128
23	162.6	64	57	126	58	129	60	132	62	136	63	139	64	142	65	144	66	146	53-57	116-125	56-60	124-132
24	165.1	65	58	129	60	132	62	136	64	140	65	143	66	146	67	148	68	150	54-58	119-128	57-61	127-135
25	167.6	66	60	133	62	136	63	140	65	144	67	147	68	151	69	152	70	153	55-60	123-132	58-63	130-140
26	170.2	67	62	137	63	140	65	144	67	148	68	151	70	155	71	157	72	158	57-62	126-136	61-65	134-144
27	172.7	68	64	141	65	144	67	148	69	152	70	155	72	159	73	162	74	163	58-63	129-139	62-67	137-147
28	175.3	69	66	145	67	148	69	152	71	156	72	159	74	163	75	166	76	167	60-65	133-143	64-68	141-151
29	177.8	70	68	149	69	152	70	155	72	159	73	162	75	166	77	170	79	173	62-67	136-147	66-70	145-155
30	180.3	71	70	153	70	155	72	158	73	162	75	166	77	170	79	174	81	177	63-68	139-150	67-71	148-158
31	182.9	72	72	157	72	159	73	162	75	165	77	169	79	173	81	177	83	182				

149. HEIGHT AND WEIGHT: MAN, NORTH AMERICA

North Americans of different racial backgrounds, socio-economic conditions, geographical areas, and different periods in American history. Data for the Negro were collected about 1925; White, Cleveland, Ohio, 1920-35; Japanese, 1920-40; Japanese reared in Japan, 1951; Dutch, Finnish, Italian, 1930-40; American Indian, Mexican, 1920-40. Lower economic groups: children of unskilled and semiskilled workers, 16 states in U. S. A., 1937-39; upper economic groups: all occupational groups other than unskilled and semiskilled, 16 states in U. S. A., 1937-39. Unskilled, semiskilled, and managerial, professional: Oregon boys of northwest European ancestry, studied in 1950. Roughly 25% in unskilled and semiskilled category, 49% in the excluded (middle) category, and 26% in the managerial and professional category. Poorest and best residential districts: white girls of Minneapolis, Minn., and Ottawa, Canada, 1930-45. Period 1860-1900 and period 1930-1950: investigations at each age were selected to approximate similar ethnic and socio-economic sampling in the 2 periods. Geographical sections of U. S. A.: about 1935. Values at age 7 are averages of means of ages 6 and 8.

Specifications	Height, ♂		Height, ♀		Weight, ♂		Weight, ♀		Specifications	Height, ♂		Height, ♀		Weight, ♂		Weight, ♀	
	cm	in.	cm	in.	kg	lb	kg	lb		cm	in.	cm	in.	kg	lb	kg	lb
1 Birth: Negro	49.6	19.5	48.7	19.1	3.2	7.1	3.1	6.8	42 10 yr: Period 1860-1900	129.6	51.0						
2 White	50.8	20.0	50.2	19.7	3.5	7.8	3.4	7.6	43 Period 1930-1950	139.2	54.8						
3 Period 1860-1900	50.4	19.8							44 Northeastern USA	135.1	53.2	135.1	53.2	30.5	67.1	30.3	66.7
4 Period 1930-1950	50.7	19.9							45 Northcentral USA	135.4	53.3	134.4	52.9	30.5	67.1	30.1	66.2
5 2 yr: Japanese	83.8	33.0	82.4	32.4					46 Southcentral USA	134.9	53.1	134.1	52.8	30.2	66.4	29.3	64.5
6 White	89.6	35.2	85.4	33.6	13.4	29.6	12.5	27.5	47 Western USA	134.9	53.1	134.6	53.0	29.6	65.1	28.6	62.9
7 Period 1860-1900	81.6	32.1							48 11 yr: Dutch	144.3	56.8			33.8	74.4		
8 Period 1930-1950	86.9	34.2							49 Finnish	141.6	55.7			33.4	73.5		
9 7 yr: Dutch	123.3	48.5			22.9	50.4			50 Indian, American	138.9	54.7			30.3	66.7		
10 Finnish	121.2	47.7			23.5	51.7			51 Italian	139.1	54.8			32.1	70.6		
11 Indian, American	120.8	47.6	117.0	46.0	21.6	47.5	20.3	44.7	52 Japanese, reared in Japan	132.1	52.0	132.5	52.2	28.8	63.4	29.2	64.2
12 Italian	119.3	47.0			22.7	49.9			53 Mexican	138.2	54.8						
13 Japanese			114.1	44.9			20.7	45.6	54 Negro	140.9	55.4	141.2	55.5				
14 Japanese, reared in Japan	113.9	44.8	112.7	44.4	20.4	44.9	19.7	43.3	55 White	142.7	56.2	143.5	56.5	35.2	77.6	35.8	79.0
15 Mexican			117.0	46.0			21.0	46.2	56 14 yr: Indian, American			150.8	59.4			42.8	94.2
16 Negro	120.9	47.5	120.4	47.3			22.1	48.6	57 Japanese			150.6	59.3			43.3	95.3
17 White	122.5	48.2	121.6	47.9	24.0	52.8	23.4	51.6	58 Japanese, reared in Japan	148.4	58.4	146.7	57.8	40.5	89.1	41.2	90.6
18 Lower economic groups	♂ 119.3 cm; 47.0 in.				♂ 22.1 kg; 48.6 lb				59 Mexican			152.0	59.8			44.5	97.9
19 Upper economic groups	♂ 120.8 cm; 47.6 in.				♂ 22.9 kg; 50.4 lb				60 Negro	156.5	61.5	154.7	60.8	48.0	105.8	47.7	105.2
20 Unskilled, semiskilled	121.4	47.8			23.3	51.3			61 White	160.0	63.0	158.2	62.3	48.9	107.9	49.1	108.5
21 Managerial, professional	123.6	48.7			24.5	53.9			62 Period 1860-1900	151.8	59.8						
22 Poorest residential dist.			118.9	46.8			21.4	47.1	63 Period 1930-1950	163.7	64.4						
23 Best residential dist.			122.0	48.0			22.8	50.2	64 Northeastern USA	155.4	61.2	155.7	61.3	45.2	99.4	48.1	105.8
24 Period 1860-1900	114.3	45.0							65 Northcentral USA	155.7	61.3	155.2	61.1	45.8	100.8	46.5	102.3
25 Period 1930-1950	122.4	48.2							66 Southcentral USA	155.7	61.3	155.4	61.2	44.6	98.1	45.2	99.4
26 Northeastern USA	119.6	47.1	118.4	46.6	22.9	50.4	22.5	49.5	67 Western USA	153.2	60.3	153.9	60.6	41.2?	90.6?	45.7	100.5
27 Northcentral USA	120.0	47.2	118.9	46.8	22.7	49.9	22.2	48.8	68 15 yr: Dutch	168.6	66.4			50.5	111.1		
28 Southcentral USA	118.9	46.8	118.1	46.5	22.2	48.8	21.4	47.1	69 Finnish	164.4	64.7			52.1	114.6		
29 Western USA	118.6	46.7	118.9	46.8	21.9	48.2	21.4	47.1	70 Indian, American	160.5	63.2			45.2	99.4		
30 10 yr: Indian, American			131.7	51.8			27.3	60.1	71 Italian	161.4	63.5			50.9	112.0		
31 Japanese			129.6	51.0			27.8	61.2	72 16 yr: Japanese, reared in Japan	157.7	62.1	150.3	59.2	49.1	108.0	47.2	103.8
32 Japanese, reared in Japan	127.6	50.2	127.3	50.1	26.4	58.1	26.1	57.4	73 Negro	161.0	63.3	158.1	62.1	53.0	116.9	53.0	116.9
33 Mexican			132.2	52.0			28.2	62.0	74 White	166.6	65.6	160.5	63.2	55.1	121.7	52.1	115.0
34 Negro	135.3	53.2	135.2	53.1			30.7	67.5	75 19 yr: Japanese, reared in Japan	161.1	63.4	150.7	59.2				
35 White	137.9	54.3	137.7	54.2	32.0	70.7	31.8	70.3	76 Negro	172.9	67.9	159.9	62.8	68.1	150.2		
36 Lower economic groups	♂ 135.0 cm; 53.1 in.				♂ 29.7 kg; 65.3 lb				77 White	173.8	68.3	164.6	64.7	68.5	151.2	58.2	128.6
37 Upper economic groups	♂ 136.6 cm; 53.8 in.				♂ 31.1 kg; 68.4 lb				78 Period 1860-1900	172.1	67.8						
38 Unskilled, semiskilled	137.8	54.3			32.3	71.1			79 Period 1930-1950	175.6	69.1						
39 Managerial, professional	140.7	55.4			34.3	75.5			80 25 yr: Japanese, reared in Japan	161.8	63.7	150.4	59.2				
40 Poorest residential dist.			134.3	52.9			29.0	63.8	81 Period 1860-1900	171.8	67.6						
41 Best residential dist.			138.7	54.6			31.8	70.0	82 Period 1930-1950	173.5	68.3						

150. HEIGHT AND WEIGHT: MAN, VARIOUS NATIONALITIES

Data are from surveys conducted over the past 25 or more years. Values in parentheses are ranges and correspond to estimate "b" of the 95% range (cf Introduction).

Specifications		Height, Male		Height, Female		Weight, Male		Weight, Female	
		cm	in	cm	in	kg	lb	kg	lb
1	Birth: USA White	50.8(46.8-54.8)	19.9(18.4-21.5)	50.2(46.4-54.1)	19.7(18.2-21.2)	3.5(2.2-4.9)	7.8(4.9-10.7)	3.4(2.5-4.4)	7.6(5.5-9.6)
2	USA Negro	49.6	19.5	48.7	19.1	3.2(3.0-3.4)	7.1(6.6-7.4)	3.1(2.9-3.3)	6.8(6.4-7.3)
3	African Pygmy	45.9	18.0	46.4	18.2	3.6	7.9	3.7	8.2
4	British	51.2	20.1	50.8	20.0	3.4	7.4	3.3	7.3
5	Chinese	48.2	18.9	48.2	18.9	3.1	6.8	3.0	6.6
6	Danish					3.4	7.5	3.3	7.3
7	French	49.9	19.6	49.2	19.3	3.1	6.8	3.1	6.8
8	German	51.0	20.0	50.5	19.8	3.5	7.7	3.3	7.3
9	Japanese	50.2	19.7	49.3	19.4	3.05	6.72	2.97	6.54
10	Russian	48.6	19.1	48.6	19.1	3.4	7.5	3.3	7.3
11	Swiss	50.8	20.0	50.2	19.7	3.3	7.3	3.1	6.8
12	1 yr: USA White	75.2(67.3-83.1)	29.6(26.5-32.7)	75.4(66.5-84.3)	29.6(26.1-33.1)	10.9(7.0-14.8)	24.0(15.4-32.6)	10.3(7.9-12.6)	22.6(17.4-27.8)
13	USA Negro	74.9(62.1-87.7)	29.4(24.4-34.5)	83.7	32.9	8.6(6.5-10.6)	19.0(14.3-23.4)	8.6(6.1-11.0)	19.0(13.4-24.2)
14	African Pygmy	71.0	27.9	65.0	25.5			7.0	15.4
15	Austrian	76	29.9	75	29.5	10.2	22.5	9.8	21.6
16	British	70.8	27.8	69.8	27.4	9.3	20.5	8.8	19.4
17	Chinese	73.5	28.9	71.4	28.1				
18	German	75.0	29.5	74.5	29.3	9.7	21.4	9.5	20.9
19	Japanese	76.4	30.1	75.6	30.0	9.7	21.4	9.3	20.5
20	2 yr: USA White	89.6(82.4-96.8)	35.2(32.4-38.0)	85.4(78.8-91.9)	33.6(31.0-36.1)	13.4(10.6-16.3)	29.6(23.4-35.8)	12.5(10.3-14.7)	27.5(22.6-32.4)
21	USA Negro	89.1(77.6-100.6)	35.0(30.5-39.5)	85.9(77.8-94.0)	33.8(20.6-36.9)				
22	Canadian	88.1	34.7	85.3	33.6	13.6	30.0	12.7	28.0
23	3 yr: USA White	96.8(89.3-104.4)	38.0(35.1-41.0)	95.9(87.5-104.3)	37.7(34.4-41.0)	15.3(12.7-17.8)	33.7(28.1-39.3)	15.1(11.1-19.2)	33.4(24.4-42.3)
24	USA Negro	95.2(83.4-107.0)	37.4(32.8-42.1)	95.8(86.6-105.0)	37.7(34.0-41.3)				
25	African Pygmy	88.6	34.8						
26	Austrian	95	36.9	94	36.2	14.5	32.0	14.0	30.9
27	British	96.3	37.8	96.0	37.7	13.7	30.2	13.2	29.1
28	Canadian	93.0	36.6	91.4	36.0	14.5	32	14.0	31
29	Chinese	92.0	36.2	89.7	35.1				
30	Czechoslovakian	89.7	35.3	87.7	34.5				
31	German	93.0	36.5	92.5	36.4	14.1	31.1	13.7	30.2
32	Japanese	91.5	36.0	90.8	35.7	13.6	30.0	13.2	29.1
33	4 yr: USA White	103.9(94.5-113.3)	40.9(37.2-44.6)	103.9(94.5-113.3)	40.9(37.2-44.6)	17.3(13.3-21.3)	38.2(29.4-47.0)	16.9(12.6-21.2)	37.3(27.9-46.7)
34	USA Negro	102.0(90.9-113.1)	40.1(35.7-44.4)	100.6(88.3-112.9)	39.5(34.7-44.4)				
35	Canadian	99.6	39.2	99.6	39.2	16.8	37	16.3	36
36	Japanese	98.3	38.7	97.1	38.2	15.3	33.7	14.7	32.4
37	5 yr: USA White	111.5(101.6-121.4)	43.9(40.0-47.8)	110.7(100.8-120.7)	43.6(39.7-47.5)	19.6(14.7-24.5)	43.2(32.4-54.0)	19.0(13.8-24.3)	42.0(30.4-53.6)
38	USA Negro	110.0(98.9-121.1)	43.2(38.9-47.6)	109.9(98.7-121.1)	43.2(38.8-47.6)				
39	African Pygmy	100.4	39.5	98.1	38.6	13.5	29.7	13.5	29.7
40	Austrian	108	42.4	107	42.1	18.5	40.8	18.0	39.7
41	British	108.2	42.5	107.9	42.4	15.5	34.2	15.9	35.0
42	Canadian	106.4	41.9	106.2	41.8	18.1	40	18.6	41
43	Chinese	104.4	41.0	108.0	42.4	14.9	32.8	14.0	30.9
44	Czechoslovakian	103.5	40.7	102.7	40.4	20.5	45.2	19.1	42.1
45	French	107.9	42.4	106.9	42.0	18.4	40.6	17.8	39.2
46	German	107.0	42.1	106.5	41.9	18.6	41.0	17.8	39.2
47	Japanese	104.0	40.1	103.3	40.7	16.7	36.8	16.2	35.7
48	6 yr: USA White	117.1(106.7-127.5)	46.1(42.0-50.2)	116.3(105.9-126.7)	45.8(41.7-49.9)	21.6(15.9-27.2)	47.6(35.2-60.0)	21.0(15.0-27.0)	46.4(33.1-59.7)
49	USA Negro	116.0(103.8-128.2)	45.6(40.8-50.4)	116.2(103.5-128.9)	45.7(40.7-50.7)				
50	Canadian	113.3	44.6	112.3	44.2	20.8	46	19.9	44
51	Japanese	109.3	43.0	108.3	42.6	18.4	40.6	17.5	38.6
52	7 yr: USA White	122.4(11.5-133.4)	48.2(43.9-52.5)	121.7(110.7-132.6)	47.9(43.6-52.2)	23.8(17.5-30.1)	52.5(38.6-66.4)	23.2(16.5-29.9)	51.2(36.5-65.9)
53	USA Negro	120.3(108.9-131.7)	47.3(42.8-51.8)	120.8(105.7-135.9)	47.5(41.5-53.4)				
54	African Pygmy	103.9	40.8	102.8	40.4	17.6	38.8		
55	Austrian	119	46.8	118	46.4	22.5	49.6	22.0	48.5
56	British	118.1	46.4	117.9	46.3	19.8	43.6	19.3	42.5
57	Canadian	119.4	47.0	118.1	46.5	22.7	50	22.2	49
58	Chinese	114.6	45.0	117.2	46.1	18.4	40.6	20.1	44.3
59	Czechoslovakian	115.6	45.4	115.0	45.2	24.3	53.6	23.3	51.4
60	Danish	118.5	46.5	117.9	46.3	21.8	48.0	21.5	47.4

61	French	117.7	46.3	116.4	45.7	22.2	48.9	21.2	46.7
62	German	119.5	47.0	118.5	46.6	22.2	48.9	21.6	47.6
63	Japanese	114.4	45.0	113.5	44.7	20.3	44.7	19.5	43.0
64	Spanish	117	46.0	116	45.6	21.6	47.6	21.5	47.4
65	Swiss	120	47.2	119.0	46.8	22.2	48.9	21.6	47.6
66	8 yr: USA White	128.0(116.6-139.4)	50.4(45.9-54.9)	127.0(115.6-138.4)	50.0(45.5-54.5)	26.4(18.6-34.1)	58.2(41.1-75.3)	25.8(17.4-34.1)	56.9(38.5-75.3)
67	USA Negro	125.8(113.3-138.3)	49.4(44.5-54.4)	124.6(111.0-138.2)	49.0(43.6-54.3)				
68	Canadian	124.7	49.1	124.2	48.9	25.8	57	25.8	57
69	Japanese	118.5	46.7	118.6	46.7	22.3	49.1	21.9	48.2
70	9 yr: USA White	133.1(121.2-144.8)	52.4(47.7-57.1)	132.1(120.1-144.0)	52.0(47.3-56.7)	29.2(20.5-37.9)	64.4(45.2-83.6)	28.5(18.7-38.4)	63.0(41.2-84.8)
71	USA Negro	130.8(118.5-143.1)	51.4(46.6-56.2)	131.3(118.7-143.9)	51.6(46.7-56.6)				
72	African Pygmy	113.3	44.5	113.0	44.0				
73	Argentinian	123	48.3	122	47.9	28.1	61.9	27.6	60.8
74	Austrian	128	50.3	127	49.9	26.7	58.8	26.0	57.3
75	British	128.0	50.3	127.8	50.2	23.4	51.6	22.0	48.4
76	Canadian	130.3	51.3	129.5	51.0	28.5	63	28.1	62
77	Chinese	123.7	48.6	126.6	49.8	22.2	48.9	23.4	51.6
78	Czechoslovakian	126.6	49.5	125.9	49.1	28.1	61.9	27.8	61.3
79	Danish	127.9	50.3	127.5	50.1	26.2	57.7	26.2	57.7
80	French	127.9	50.3	127.7	50.2	27.0	59.5	26.8	59.1
81	German	129.0	50.7	128.5	50.5	26.7	58.8	25.9	57.1
82	Japanese	124.1	48.9	123.6	48.7	24.7	54.4	23.8	52.5
83	Russian	125.3	49.2	124.5	48.9				
84	Spanish	123	48.3	124.6	49.0	24.7	54.4	26.0	57.3
85	Swiss	129	50.7	129.1	50.7	26.3	58.0	26.2	57.7
86	10 yr: USA White	137.9(125.5-150.4)	54.3(49.4-59.2)	137.7(124.7-150.6)	54.2(49.1-59.3)	32.0(21.8-42.2)	70.7(48.2-93.2)	31.8(20.1-43.6)	70.3(44.4-96.2)
87	USA Negro	135.3(121.6-149.0)	53.2(47.8-58.6)	135.2(120.4-150.0)	53.1(47.3-58.9)				
88	Canadian	135.9	53.5	135.4	53.3	31.7	70	31.3	69
89	Japanese	128.9	50.7	128.6	50.6	26.9	59.2	26.5	58.3
90	11 yr: USA White	142.7(129.8-155.7)	56.2(51.1-61.3)	143.5(129.5-157.5)	56.5(51.0-62.0)	35.2(23.5-46.8)	77.6(51.9-103.3)	35.8(22.0-49.6)	79.0(48.6-109.4)
91	USA Negro	140.9(129.0-152.8)	55.4(50.7-60.1)	141.2(124.1-158.3)	55.5(48.8-62.2)				
92	African Pygmy								
93	Argentinian	132	51.9	132	51.9	23.0	50.7	18.5	40.8
94	Austrian	137	53.8	138	54.2	33.1	73.0	33.9	74.7
95	British	136.7	53.7	137.9	54.2	31.8	70.1	31.5	69.4
96	Canadian	140.7	55.4	140.5	55.3	26.8	59.1	27.2	59.9
97	Chinese	131.3	51.6	135.4	53.2	34.9	77	34.9	77
98	Czechoslovakian	133.4	52.4	133.4	52.4	26.5	58.4	28.7	63.3
99	Danish	137.5	54.0	137.5	54.0	32.0	70.5	33.6	74.1
100	French	137.8	54.2	138.6	54.5	31.8	70.1	32.3	71.2
101	German	137.5	54.0	139.0	54.6	32.6	71.9	33.9	74.7
102	Japanese	132.9	52.2	134.0	52.8	31.5	69.4	31.4	69.2
103	Spanish	132.7	52.2	134	52.7	29.3	64.6	29.8	65.7
104	Swiss	138	54.2	137.3	54.0	29.0	63.9	31.5	69.4
105	12 yr: USA White	147.8(133.4-162.3)	58.2(52.5-63.9)	149.9(135.8-164.3)	59.0(53.3-64.7)	38.8(24.7-52.8)	85.6(54.6-116.6)	40.6(24.8-56.4)	89.7(54.8-124.6)
106	USA Negro	144.8(129.2-160.4)	56.9(50.8-63.0)	149.0(136.3-161.7)	58.6(53.6-63.5)	37.0(26.8-47.2)	81.6(59.1-104.0)	39.9(34.8-45.0)	88.1(76.7-99.2)
107	Canadian	145.8	57.4	147.8	58.2	38.1	84	41.7	92
108	Japanese	137.7	54.2	139.5	54.9	32.0	70.6	33.6	74.1
109	13 yr: USA White	153.7(137.7-169.7)	60.5(54.2-66.8)	153.9(141.0-166.9)	60.6(55.5-65.7)	43.3(27.1-59.5)	95.6(59.9-131.3)	45.4(29.4-61.4)	100.3(65.0-135.6)
110	USA Negro	150.1(133.0-166.3)	59.0(52.6-65.4)	153.7(137.5-169.9)	60.4(54.0-66.8)	43.9(34.5-53.3)	96.7(76.0-117.5)	43.8(23.2-64.4)	96.7(51.1-142.0)
111	African Pygmy	115.1	45.2						
112	Argentinian	142	55.8	145	57.0	40.6	89.5	41.9	92.3
113	Austrian	148	58.2	149	58.6	38.5	84.9	38.5	84.9
114	British	155.1(136.9-173.5)	61.1(53.9-68.3)	154.4(141.0-167.6)	60.8(55.5-68.0)	42.7(26.8-58.7)	94.3(59.1-129.5)	45.1(31.1-59.1)	99.6(68.7-130.5)
115	Canadian	150.6	59.3	153.4	62.6	42.6	94	46.3	102
116	Chinese	141.1	55.4	145.7	57.3	32.3	71.2	37.0	81.5
117	Czechoslovakian	142.9	56.2	144.7	56.9	34.3	75.6	35.0	77.1
118	Danish	146.5	57.6	148.6	58.4	38.1	84.0	40.8	89.9
119	German	147.0	57.8	151.0	59.3	37.5	82.7	40.2	88.6
120	Japanese	142.6	56.1	144.4	56.9	35.6	78.5	38.2	84.2
121	Spanish	139.6	54.9	143.7	56.5	35.7	78.7	38.0	83.8
122	14 yr: USA White	160.0(143.0-177.0)	63.0(56.3-69.7)	158.2(146.3-170.2)	62.3(57.6-67.0)	48.9(31.0-66.7)	107.9(68.5-147.3)	49.1(33.9-64.4)	108.5(74.8-142.2)
123	USA Negro	156.5(140.0-172.9)	61.5(55.1-67.9)	154.7(140.5-168.9)	60.8(55.2-66.4)	48.0(38.6-57.4)	105.8(85.1-126.5)	47.7(27.1-68.3)	105.2(59.7-150.5)
124	British	155.1(136.9-173.5)	61.1(53.9-68.3)	154.4(141.0-167.6)	60.8(55.5-66.0)	42.7(26.8-58.7)	94.3(59.1-129.5)	45.1(31.1-59.1)	99.6(68.7-130.5)
125	Canadian	158.0	62.2	155.7	61.3	48.9	108	48.5	107
126	Japanese	149.7	58.9	147.5	58.1	41.1	90.6	41.5	91.4

150. HEIGHT AND WEIGHT: MAN, VARIOUS NATIONALITIES (Concluded)

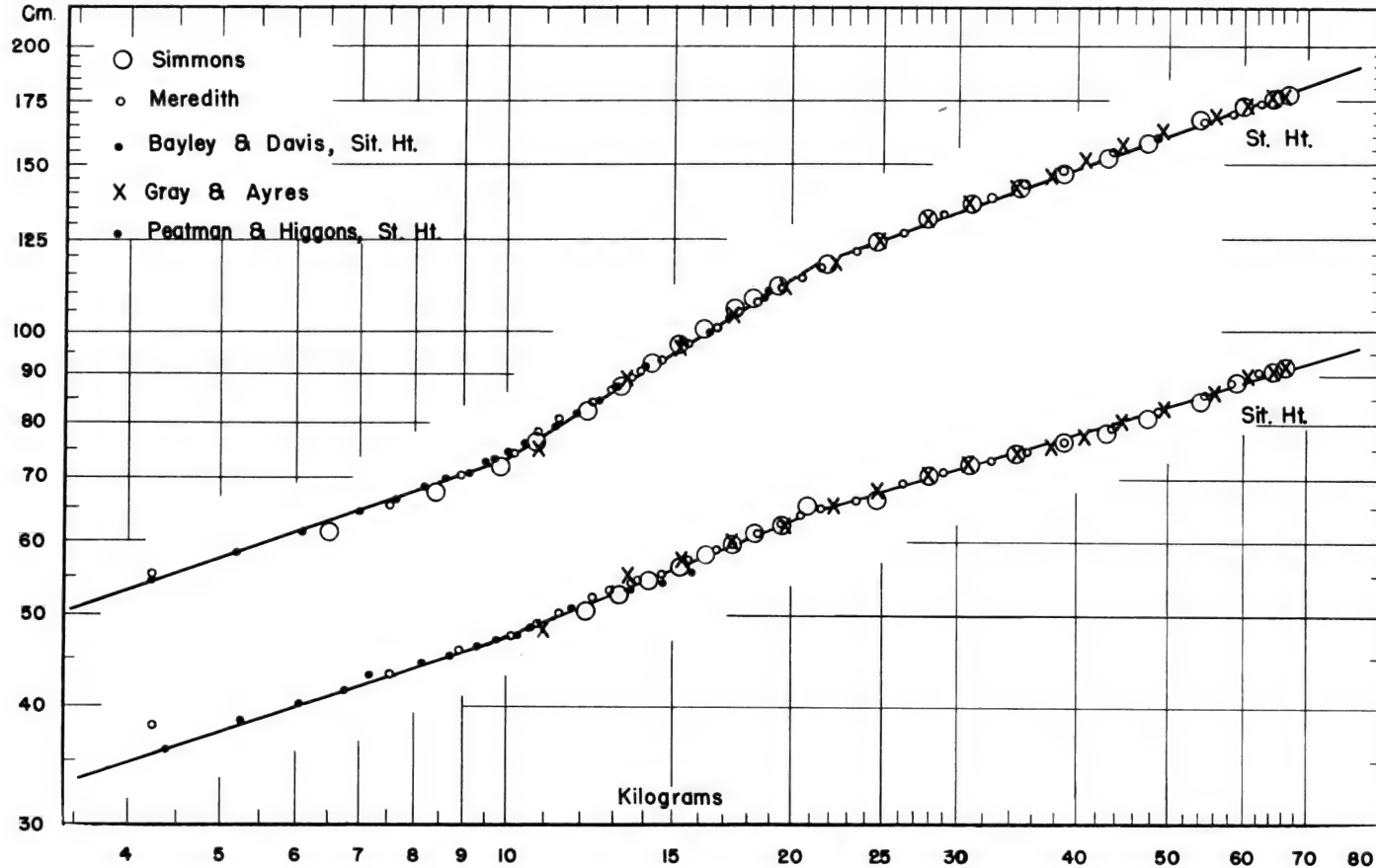
Data are from surveys conducted over the past 25 or more years. Values in parentheses are ranges and correspond to estimate "b" of the 95% range (cf Introduction).

Specifications	Height, Male		Height, Female		Weight, Male		Weight, Female	
	cm	in	cm	in	kg	lb	kg	lb
127 15 yr: USA White	166.6(151.1-182.1)	65.6(59.5-71.7)	160.5(149.1-172.0)	63.2(58.7-67.7)	55.1(36.8-73.4)	121.7(81.3-162.1)	52.1(37.7-66.5)	115.0(83.2-146.8)
128 USA Negro	161.0(145.8-176.2)	63.3(57.3-69.2)	158.1(146.6-169.6)	62.1(57.6-66.6)	53.0(41.6-64.4)	116.9(91.7-141.9)	53.0(28.3-77.7)	116.9(62.4-171.3)
129 British	158.6(140.2-177.0)	62.4(55.2-69.7)	155.8(144.0-167.9)	61.4(56.7-66.1)	45.8(28.6-63.0)	101.1(63.2-139.0)	47.7(32.6-62.7)	105.2(72.0-138.4)
130 Canadian	164.3	64.7	158.0	62.2	53.9	119	50.7	112
131 Czechoslovakian	156	61.3			52.1	114.8		
132 Danish	160.1	62.9	158.0	62.1	49.2	108.4	49.6	109.3
133 German	160.5	63.1	160.0	62.9	48.1	106.0	49.5	109.1
134 16 yr: USA White	170.9(157.0-184.9)	67.3(61.8-72.8)	161.3(150.4-172.2)	63.5(59.2-67.8)	59.8(43.0-76.5)	131.9(94.9-168.9)	53.3(39.1-67.4)	117.6(86.4-148.8)
135 USA Negro	163.6(149.0-178.2)	64.3(58.6-70.0)	157.8(146.4-169.2)	62.0(57.5-66.5)	57.0(45.8-68.2)	125.7(100.9-150.3)	56.9(32.6-81.2)	125.7(71.9-179.0)
136 British	163.9(146.1-181.6)	64.5(57.5-71.5)	157.6(145.0-170.0)	62.0(57.1-66.9)	50.6(33.3-67.9)	111.7(73.5-149.9)	49.8(35.7-64.0)	110.0(78.7-141.3)
137 Canadian ¹	169.4	66.7	158.7	62.5	61.6	136	54.4	120
138 Japanese	158.9	62.6	150.7	59.3	49.9	110.0	47.7	105.1
139 17 yr: USA White	172.1(159.5-184.7)	67.6(62.7-72.6)	161.5(150.6-172.5)	63.6(59.3-67.9)	63.6(49.2-78.0)	140.4(108.6-172.3)	53.9(40.1-67.7)	119.0(88.6-149.4)
140 USA Negro	167.2(157.3-183.0)	66.0(61.8-71.9)	158.5(145.8-171.2)	62.3(57.3-67.3)	63.8(48.6-79.1)	140.9(107.2-174.6)		
141 British	167.4(152.1-182.6)	65.9(59.9-71.9)	157.8(146.0-169.7)	62.1(57.5-66.8)	54.4(39.3-69.4)	120.0(86.7-153.3)	51.1(37.3-64.9)	112.8(82.4-143.2)
142 Chinese	162.4	63.8	154.3	60.6	48.3	106.5	47.5	104.7
143 Czechoslovakian	159	62.5			61.3	135.1		
144 German	170.5	67.0	164.0	64.5	59.8	131.8	56.3	124.1
145 18 yr: USA White	173.5(161.1-185.8)	68.2(63.3-73.0)	163.7(156.0-171.4)	63.3(61.3-67.4)	67.0(50.3-83.6)	147.8(111.1-184.6)	57.4(46.0-68.8)	125.6(101.3-151.5)
146 USA Negro	173.4(158.5-188.2)	68.1(62.3-74.0)	159.2(148.1-170.3)	62.6(58.2-66.9)	67.0(53.0-81.0)	147.8(116.9-178.7)		
147 British	168.4(153.7-183.1)	66.3(60.5-72.1)	157.9(145.5-170.4)	62.2(57.3-67.1)	56.4(41.5-71.3)	124.5(91.7-157.3)	51.8(37.5-66.1)	114.4(82.8-146.0)
148 Canadian ²	172.7	68.0	159.0	62.6	65.2	144	56.2	124
149 Japanese	161.2	63.5	151.7	59.7	53.5	117.9	49.6	109.3
150 19 yr: USA White	173.8(161.4-186.3)	68.3(63.4-73.2)	164.6(155.5-173.7)	64.7(61.1-68.3)	68.5(51.4-85.5)	151.2(113.6-188.8)	58.2(48.9-67.4)	128.6(107.8-148.6)
151 USA Negro	172.9(160.1-185.6)	67.9(62.5-73.0)	159.9(147.2-172.6)	62.8(57.8-67.8)	68.1(53.0-83.1)	150.2(117.0-183.4)		
152 British	169.5(155.2-183.6)	66.7(61.1-72.3)	158.2(147.1-169.4)	62.3(57.9-66.7)	57.9(43.2-72.6)	127.8(95.4-160.2)	52.5(38.3-66.8)	116.0(84.6-147.4)
153 Chinese	165.0	64.8	152.0	59.7	52.6	115.9	44.4	97.9
154 German	174.0	68.4	165.0	64.8	64.5	142.2	59.0	130.0
155 20-24 yr: USA White	174.2(161.6-186.5)	68.4(63.5-73.3)	161.5	63.6	70.0(52.2-88.0)	154.7(115.2-194.2)	55.7	123.0
156 USA Negro	173.1(160.4-185.8)	68.0(63.0-73.0)	159.4(145.0-173.8)	62.6(57.0-68.3)	69.7(53.4-85.9)	153.8(118.0-189.7)		
157 British	170.2(156.7-183.7)	67.0(61.7-72.3)	158.3(146.7-170.0)	62.3(57.8-66.9)	60.6(45.8-75.4)	133.8(101.1-166.6)	53.0(38.2-68.0)	117.1(84.2-150.0)
158 Canadian	172.5	67.9	159.5	62.8	69.8	154	56.2	124
159 Chinese ³	166.0	65.2	156.0	61.3	63.8	118.6	49.0	108.0
160 German ⁴	167.0	65.6	157.4	61.9	59.5	131.1	53.2	117.3
161 Japanese ⁵	162.4	63.9	150.8	59.3	56.2	123.9	49.0	108.0
162 25-29 yr: USA White	173.9(161.7-186.1)	68.3(63.6-73.1)	161.0	63.4	71.5(53.4-89.5)	157.8(117.9-197.6)	56.5	124.7
163 USA Negro	173.0(160.7-185.4)	68.0(63.1-72.8)	158.7(142.1-175.3)	62.4(55.8-68.9)	70.7(52.8-88.5)	156.0(116.5-195.4)		
164 British	169.6(156.5-182.6)	66.8(61.6-71.9)	157.8(145.0-170.7)	62.1(57.1-67.2)	61.7(46.4-77.1)	136.3(102.4-170.2)	53.1(37.3-69.0)	117.3(82.3-152.3)
165 Canadian	173.5	68.3	159.2	62.7	72.5	160	57.1	126
166 German ⁵	168.2	66.1	157.8	62.0	66.2	145.9	54.8	120.8
167 Japanese	162.1	63.8	150.4	59.2	55.1	121.4	48.3	106.5
168 30-34 yr: USA White	173.3(161.1-185.6)	68.1(63.3-73.3)	161.0	63.4	71.6(53.4-89.9)	158.1(117.8-198.4)	58.7	129.5
169 British	169.5(156.5-182.6)	66.7(61.6-71.9)	157.5(145.3-169.7)	62.0(57.2-66.8)	62.7(46.2-79.2)	138.4(102.0-174.8)	54.2(36.6-71.8)	119.6(80.8-158.4)
170 Canadian	172.7	68.0	159.5	62.8	75.7	167	58.9	130
171 German ⁶	168.6	66.3	158.0	62.1	66.1	145.7	55.3	121.9
172 30-39 yr: USA Negro	170.0(157.9-182.1)	66.8(62.1-71.6)	158.8(146.2-171.4)	62.4(57.5-67.4)	71.9(52.4-91.3) ⁷	158.6(115.7-201.5) ⁷		
173 31-40 yr: Japanese	160.4	63.1	149.3	58.8	54.7	120.6	48.2	106.2
174 35-44 yr: USA White			160.3	63.1			62.5	138.0
175 British	168.6(154.8-182.4)	66.4(61.0-71.8)	156.8(144.2-169.6)	61.7(56.8-66.7)	62.6(45.5-79.6)	138.1(100.4-175.8)	56.2(36.0-76.4)	124.0(79.5-168.7)
176 Canadian	171.5	67.5	158.5	62.4	75.7	167	61.2	135
177 40 yr: German	168.6	66.3	158.0	62.1				
178 40-49 yr: USA Negro	170.6(157.9-183.3)	67.0(62.1-72.0)	158.7(147.3-170.1)	62.3(57.9-66.8)				
179 41-50 yr: Japanese	159.2	62.7	147.8	58.2	54.6	120.5	48.0	105.8
180 45-54 yr: USA White			159.4	62.8			67.0	147.8
181 British	167.2(154.0-180.2)	65.8(60.6-71.0)	155.8(143.3-168.5)	61.4(56.4-66.4)	62.2(43.9-80.5)	137.2(96.8-177.7)	58.6(35.8-81.4)	129.2(78.9-179.6)
182 Canadian	169.9	66.9	157.0	61.8	74.3	164	65.2	144
183 55-64 yr: USA White			158.0	62.2			65.5	144.5
184 British	166.5(152.8-178.9)	65.3(60.2-70.5)	154.5(141.5-167.6)	60.8(55.7-66.0)	62.2(43.0-81.2)	137.2(94.8-179.5)	58.2(34.8-82.0)	128.5(76.9-180.0)
185 Canadian	167.6	66.0	155.7	61.3	72.9	161	66.6	147
186 >64 yr: USA White			156.6	61.7			62.7	138.5
187 British	163.5(147.1-179.9)	64.4(57.9-70.8)	152.7(140.6-164.9)	60.1(55.3-64.9)	60.1(40.8-79.3)	132.6(90.2-175.0)	54.3(34.7-73.9)	119.9(76.7-163.2)
188 Canadian	166.4	65.5	153.9	60.6	70.2	155	62.5	138

/1/ 16 and 17 yr. /2/ 18 and 19 yr. /3/ 21 yr. /4/ 20 yr. /5/ 25 yr. /6/ 30 yr. /7/ 30-34 yr.

151. REGRESSION OF SITTING AND STANDING HEIGHTS ON BODY WEIGHT: MAN

These graphs are based on five large groups of measurements on males from infancy to old age. The five groups as listed in the upper left corner of the chart, contain 6,704, 16,510, 469, 3,097, and 2,638 values, respectively. The standing height curve is based on a total of 17,523 values; that for sitting height, on 14,992 values. In each of the five groups care was taken to exclude persons not in good health. Curves representing ordinary range limits (95% range) are not available, but would be expected to lie above and below each of these curves and parallel to it. The upper of such curves for standing height would represent the ordinarily encountered limit in the direction of slenderness, the lower the ordinarily encountered limit in the direction of heaviness of build. Evidence indicates that curves for females (not represented) are identical in slope and position with these for males. The means for males simply lie farther to the right along the curve than do the means for females of the same age. The line slopes for the standing height curve are 0.34, 0.63, and 0.35, with the breaks at 10 kg and 22 kg. For sitting height the comparable slopes are 0.34, 0.41, and 0.30. The relationships between standing height and weight for the three weight ranges are expressed by the formulae, $H/W^{0.34}$, $H/W^{0.63}$, and $H/W^{0.35}$.



152. LIFE SPAN: ANIMALS

Animals in wild state are indicated by an asterisk (*). When no symbol (♂, ♀) precedes value, sex of animal is unspecified.

Species			Recorded Life Span		Species			Recorded Life Span	
			Av yr	Max yr				Av yr	Max yr
Vertebrata					Vertebrata (continued)				
Mammalia					Mammalia (concluded)				
1	Agouti (<i>Dasyprocta aguti</i>)		6	>10	83	Seal, common (<i>Phoca vitulina</i>)			>14
2	Alpaca (<i>Lama pacos</i>)		12	>17	84	Sheep, domestic (<i>Ovis aries</i>)	10-15		20
3	Anteater, spiny (<i>Tachyglossus aculeatus</i>)			50 ¹	85	Shrew, jumping (<i>Elephantulus rozeti</i>)			3.4
4	Antelope, pronghorned (<i>Antilocapra americana</i>)		8	15	86	Skunk, Canadian (<i>Mephitis mephitis</i>)			6
5	Ape, black (<i>Cynopithecus niger</i>)*		2	18	87	Sloth, two-toed (<i>Choloepus didactylus</i>)			>11
6	Ass, African wild (<i>Equus asinus taeniopus</i>)		14.6	19.3	88	Squirrel, gray (<i>Sciurus carolinensis</i>)	9		14-15
7	Baboon, sacred (<i>Papio hamadryas</i>)		15	22.4	89	Swine (<i>Sus scrofa</i>)	16		27
8	Badger, American (<i>Taxidea taxus</i>)		11	>13	90	Tapir, Brazilian (<i>Tapirus terrestris</i>)	<6		9
9	Bat, American brown (<i>Eptesicus fuscus</i>)			2	91	Tiger (<i>Panthera tigris</i>)	11		19
10	Bear, brown (<i>Ursus arctos</i>)			34	92	Weasel (<i>Mustela nivalis</i>)			>7
11	Bear, grizzly (<i>U. horribilis</i>)		20	>31	93	Whale, arctic (<i>Balaena mysticetus</i>)	24-37 ¹		
12	Bear, polar (<i>Thalarctos maritimus</i>)		16	33	94	Wolf, European (<i>Canis lupus</i>)	12		14
13	Beaver, American (<i>Castor canadensis</i>)			21.9	95	Woodchuck (<i>Marmota monax</i>)			>9
14	Blackbuck (<i>Antelope cervicapra</i>)		7	♂15	96	Yak (<i>Peophagus gruuniensis</i>)			22
15	Buffalo, American (<i>Bison bison</i>)		10	♂22	97	Zebra, mountain (<i>Equus zebra</i>)	22		>25
16	Buffalo, African (<i>Syncerus caffer</i>)		10	>15	Maximum yr				
17	Camel, dromedary (<i>Camelus dromedarius</i>)			>25	Aves				
18	Cat, domestic (<i>Felis catus</i>)		13-17	21	98	Bird of paradise (<i>Paradisea apoda</i>)			>12
19	Cheetah (<i>Acinonyx jubatus</i>)		6	>15	99	Blackbird, European (<i>Turdus merula</i>)			18
20	Chimpanzee (<i>Pan troglodytes</i>)		15-20	37	100	Bluebird (<i>Sialia sialis</i>)			4.5
21	Chinchilla (<i>Chinchilla laniger</i>)		4	7	101	Bunting, red-headed (<i>Emberiza luteola</i>)			>13
22	Chipmunk, eastern (<i>Tamias striatus</i>)		2.5	>7	102	Buzzard, African (<i>Buteo desertorum</i>)			>18
23	Civet (<i>Viverra spp</i>)			>15	103	Canary, house (<i>Serinus canarius</i>)			24
24	Coyote (<i>Canis latrans</i>)		9	14	104	Cardinal (<i>Richmondia cardinalis</i>)			22
25	Deer, fallow (<i>Dama dama</i>)		10	♀15	105	Chickadee (<i>Parus atricapillus</i>)			>7
26	Dingo (<i>Canis dingo</i>)		3	♀12	106	Cockatoo, slender-billed (<i>Kakatoe tenuirostris</i>)			85 ¹
27	Dog, domestic (<i>C. familiaris</i>)		13-17	34	107	Condor (<i>Vultur gryphus</i>)			52
28	Dolphin (<i>Delphinus delphis</i>)		25-30		108	Coot, slaty (<i>Fulica ardesiaca</i>)			3
29	Dormouse, garden (<i>Eliomys quercinus</i>)		2-3	>5	109	Cormorant (<i>Phalacrocorax carbo</i>)			23
30	Elephant, African (<i>Loxodonta africana</i>)		24	36	110	Cowbird, bay-winged (<i>Molothrus badius</i>)			>12
31	Elephant, Indian (<i>Elephas maximus</i>)			57	111	Crane, common (<i>Grus communis</i>)			>42
32	Elk, European (<i>Alces alces</i>)		15-20	25	112	Dove, collared (<i>Turtur risorius</i>)			30-40
33	Fox, arctic (<i>Alopex lagopus</i>)		8	14	113	Duck, domestic (<i>Anas platyrhynchos domesticus</i>)			19 ²
34	Fox, red (<i>Vulpes fulva</i>)			12	114	Eagle, Chilean (<i>Geranoaetus melanoleucus</i>)			>42
35	Gazelle, Korin (<i>Gazella rufifrons</i>)			♂11	115	Egret, American snowy (<i>Leucophoyx thula</i>)			>16
36	Genet (<i>Genetta pardina</i>)		>7	12.5	116	Emu (<i>Dromiceius novaehollandiae</i>)			40 ¹
37	Gibbon (<i>Hylobates spp</i>)			>23	117	Finch, chestnut-eared (<i>Amadina castanotis</i>)			>8
38	Giraffe (<i>Giraffa camelopardalis</i>)		14	>28	118	Flamingo, European (<i>Phoenicopterus roseus</i>)			>22
39	Gnu, brindled (<i>Connochaetes taurinus</i>)			16	119	Fowl, domestic (<i>Gallus domesticus</i>)			30
40	Goat (<i>Capra hircus</i>)		8-10	18	120	Goldfinch, European (<i>Carduelis carduelis</i>)			27
41	Gorilla (<i>Gorilla gorilla</i>)			>7	121	Goose, Canadian (<i>Branta canadensis</i>)			32
42	Guinea pig (<i>Cavia porcellus</i>)		>2	>6	122	Gull, herring (<i>Larus argentatus</i>)			44
43	Hamster, common (<i>Cricetus cricetus</i>)		2	2.5	123	Heron (<i>Ardea cinerea</i>)			>24
44	Hamster, golden (<i>Mesocricetus auratus</i>)		1	1.8	124	Hornbill, Indian great (<i>Buceros bicornis</i>)			33
45	Hedgehog, European (<i>Erinaceus europaeus</i>)			2	125	Jay, blue (<i>Cyanocitta cristata</i>)			>4
46	Hippopotamus (<i>Hippopotamus amphibius</i>)		40	49 ²	126	Kingfisher, laughing (<i>Halcyon sp</i>)			11
47	Horse, domestic (<i>Equus caballus</i>)		20-30	62	127	Kiwi (<i>Apteryx australis</i>)			20 ²
48	Hyena, spotted (<i>Crocuta crocuta</i>)		12	25	128	Lovebird, gray-headed (<i>Agapornis cana</i>)			>8
49	Ibex, Nubian (<i>Capra nubiana</i>)		8.5	>10	129	Lyrebird (<i>Menura superba</i>)			>8
50	Jackal, black-backed (<i>Canis mesomelas</i>)		8	13	130	Macaw, blue-and-yellow (<i>Ara ararauna</i>)			43
51	Jaguar (<i>Panthera onca</i>)		14	>22	131	Macaw, red-and-blue (<i>A. macao</i>)			64
52	Kangaroo, red (<i>Macropus rufus</i>)			16.3	132	Magpie (<i>Pica pica</i>)			12
53	Lemur, black (<i>Lemur macaco</i>)		10	♂21	133	Mockingbird (<i>Mimus polyglottos</i>)			>6
54	Leopard (<i>Panthera pardus</i>)		14	23	134	Nightingale (<i>Luscinia luscinia</i>)			3.8
55	Lion (<i>P. leo</i>)		20-25	29	135	Nuthatch, white-breasted (<i>Sitta carolinensis</i>)			>8
56	Llama (<i>Lama glama</i>)		15	20	136	Ostrich, African (<i>Struthio camelus</i>)			50
57	Loris, slow (<i>Nycticebus coucang</i>)			10	137	Owl, barn (<i>Tyto alba</i>)			>13
58	Lynx, Canadian (<i>Lynx canadensis</i>)		6	>11	138	Owl, snowy (<i>Nyctea nyctea</i>)			24.5
59	Marmoset (<i>Hapale jacchus</i>)		11	16	139	Parrot, Maximilian's (<i>Pionus maximiliani</i>)			9
60	Marmot, alpine (<i>Marmota marmota</i>)		7	>13	140	Parakeet, ring-necked (<i>Psittacula torquatus</i>)			>20
61	Marten, pine (<i>Martes martes</i>)		10	>13.5	141	Partridge, European (<i>Perdix perdix</i>)			>5
62	Mongoose, zebra (<i>Mungos mungo</i>)		5	♀8	142	Pelican, Australian (<i>Pelecanus conspicillatus</i>)			52
63	Monkey, bonnet (<i>Macaca radiata</i>)		>12	13	143	Penguin, king (<i>Aptenodytes patagonica</i>)			26
64	Monkey, rhesus (<i>M. mulatta</i>)		15	29	144	Pheasant, ring-necked (<i>Phasianus colchicus</i>)			>27
65	Mouse, harvest (<i>Micromys minutus</i>)		2	2.5	145	Pigeon, domestic (<i>Columba livia domestica</i>)			35
66	Mouse, house (<i>Mus musculus</i>)		1-2	>3	146	Plover, old-world golden (<i>Pluvialis apricaria</i>)			>1
67	Opossum (<i>Didelphis spp</i>)			>7	147	Puffin, Atlantic (<i>Fratercula arctica</i>)			8 ²
68	Orangutan (<i>Pongo pygmaeus</i>)		8	♂26	148	Quail, European (<i>Coturnix coturnix</i>)			10
69	Otter (<i>Lutra spp</i>)			>15	149	Raven (<i>Corvus corax</i>)			69
70	Ox (<i>Bos taurus</i>)		20-25	30	150	Robin, American (<i>Turdus migratorius</i>)			>12
71	Peccary, collared (<i>Pecari tajacu</i>)			>15	151	Rook (<i>Corvus frugilegus</i>)			>14
72	Platypus (<i>Ornithorhynchus paradoxus</i>)		5		152	Skylark (<i>Alauda arvensis</i>)			24
73	Porcupine, African (<i>Hystrix cristata</i>)		8-12	>20	153	Sparrow, Italian (<i>Passer italiae</i>)			20
74	Prairie dog (<i>Cynomys ludovicianus</i>)		4	>8	154	Starling (<i>Sturnus vulgaris</i>)			>15
75	Puma (<i>Felis concolor</i>)		9	16	155	Stork, black (<i>Ciconia nigra</i>)			30
76	Rabbit, European (<i>Oryctolagus cuniculus</i>)		5-6	>13	156	Swallow (<i>Hirundo rustica</i>)			<1
77	Raccoon (<i>Procyon lotor</i>)		4	>13	157	Swan, trumpeter (<i>Cygnus buccinator</i>)			>29
78	Rat, house (<i>Rattus rattus</i>)		2-3	4	158	Thrush, song (<i>Turdus musicus</i>)			>11
79	Reindeer (<i>Rangifer tarandus</i>)			12	159	Titmouse, great (<i>Parus major</i>)			9
80	Rhinoceros, Indian great (<i>Rhinoceros unicornis</i>)		40-45	47	160	Turkey (<i>Meleagris gallopavo</i>)			>12
81	Sea lion, California (<i>Zalophus californianus</i>)		13	19	161	Vulture, griffon (<i>Gyps fulvus</i>)			41
82	Seal, cape fur (<i>Arctocephalus pusillus</i>)		13	♀20	162	Waxbill, Amandava (<i>Estrilda amandava</i>)			>10

/1/ Reported as not authenticated. /2/ Still alive at time of report.

152. LIFE SPAN: ANIMALS (Continued)

Animals in wild state are indicated by an asterisk (*). When no symbol (♂, ♀) precedes value, sex of animal is unspecified.

Species		Recorded Life Span	Species		Recorded Life Span	
		Maximum yr			Av yr	Max yr
Vertebrata (continued)			Vertebrata (concluded)			
Reptilia			Pisces (concluded)			
163	Alligator, American (<i>Alligator mississippiensis</i>)	56	242	Cod, Atlantic (<i>Gadus morhua</i>)*		13
164	Anaconda (<i>Eunectes murinus</i>)	28	243	Dogfish (<i>Scyllidae</i> sp)		>2
165	Black snake (<i>Coluber constrictor</i>)	5,3 ²	244	Eel, electric (<i>Electrophorus electricus</i>)		11.5
166	Boa constrictor (<i>Constrictor constrictor</i>)	>23	245	Eel, N. American (<i>Anguilla rostrata</i>)		6
167	Caiman, black (<i>Caiman niger</i>)	28	246	Flounder (<i>Pleuronectes flesus</i>)		10
168	Chameleon (<i>Chameleon</i> sp)	>3.5	247	Flounder, starry (<i>Platichthys stellatus</i>)		>8
169	Cobra, African black (<i>Naja melanoleuca</i>)	>26 ²	248	Flounder, winter (<i>Pleuronectes americanus</i>)		1
170	Cooter (<i>Pseudemys scripta</i>)	7	249	Gar, longnose (<i>Lepisosteus osseus</i>)*		30
171	Copperhead, N. Am. (<i>Ancistrodon contortrix</i>)	18.5 ²	250	Goldfish (<i>Cyprinus carassius auratus</i>)		25
172	Cottonmouth, N. American (<i>A. piscivorus</i>)	21	251	Grayling, American (<i>Thymallus signifer</i>)*	4	11
173	Crocodile, American (<i>Crocodylus acutus</i>)	13.5	252	Grunion (<i>Leuresthes tenuis</i>)		4
174	Garter snake (<i>Thamnophis sirtalis</i>)	6	253	Haddock (<i>Melanogrammus aeglefinus</i>)*	1.9	15
175	Gecko, Moorish wall (<i>Tarentola mauritanica</i>)	7.4	254	Halibut, Atlantic (<i>Hippoglossus hippoglossus</i>)		40
176	Gila monster (<i>Heloderma suspectum</i>)	20	255	Herring, Pacific (<i>Clupea pallasii</i>)*	5.9	19
177	Iguana, Galapagos (<i>Conolophus suberistatus</i>)	15.1	256	Lamprey, American brook (<i>Lampetra lamottei</i>)		5
178	King snake (<i>Lampropeltis getulus californiae</i>)	14.8	257	Lungfish, African (<i>Protopterus annectens</i>)		>17
179	Lizard, European glass (<i>Ophisaurus apus</i>)	24	258	Lungfish, S. American (<i>Lepidosiren paradoxa</i>)		8.3
180	Lizard, long-tailed (<i>Latastia longicaudata</i>)	2.3	259	Mackerel, jack (<i>Trachurus symmetricus</i>)		>20
181	Lizard, monitor (<i>Varanus salvator</i>)	10.8 ¹	260	Mackerel, Pacific (<i>Pneumatophorus diego</i>)		11
182	Matamora (<i>Chelys fimbriata</i>)	10.3	261	Minnow, European (<i>Phoxinus phoxinus</i>)		13
183	Puff adder (<i>Bitis arietans</i>)	13.9	262	Paddlefish (<i>Polyodon spathula</i>)		14
184	Python, African rock (<i>Python sebae</i>)	15.5	263	Perch (<i>Perca fluviatilis</i>)		>10.8
185	Rattlesnake, N. American (<i>Crotalus atrox</i>)	18.6	264	Perch, yellow (<i>P. flavescens</i>)*	3.4	13
186	Skink, sand (<i>Chalcides ocellatus</i>)	>9.5	265	Pickering, chain (<i>Esox niger</i>)*	3.3	8
187	Terrapin, Reeve's (<i>Geoclemys reevesii</i>)	24.3	266	Pike (<i>E. lucius</i>)	4.6	24
188	Tortoise, European pond (<i>Emys orbicularis</i>)	66	267	Roach (<i>Rutilus rutilus</i>)		12
189	Tortoise, Galapagos (<i>Testudo elephantopus</i>) ³	177	268	Salmon, Atlantic (<i>Salmo salar</i>)*		13
190	Tuatara (<i>Sphenodon punctatus</i>)	>28	269	Salmon, pink (<i>Oncorhynchus gorbuscha</i>)*		1.8
191	Turtle, common box (<i>Terrapene carolina</i>)	123	270	Sardine, California (<i>Sardinops caerulea</i>)*	3.3	13
192	Turtle, green (<i>Chelonia mydas</i>)	21.0 ²	271	Seahorse (<i>Hippocampus guttulatus</i>)		6
193	Turtle, musk (<i>Sternotherus odoratus</i>)	53.1 ²	272	Shark (<i>Scyliorhinus stellaris</i>)*		18
194	Turtle, snapping (<i>Chelydra serpentina</i>)	20 ²	273	Shiner, common (<i>Notropis cornutus</i>)*		6
195	Water moccasin (<i>Ancistrodon piscivorus</i>)	21	274	Smelt, American (<i>Osmerus mordax</i>)*	2.3	5
196	Water snake (<i>Matrix sipedon</i>)	7	275	Smelt, jack (<i>Atherinopsis californiensis</i>)		9-10
197	Whip snake (<i>Masticophis flagellum</i>)	13.4	276	Sole, Dover (<i>Microstomus pacificus</i>)		15
198	Viper, cape (<i>Causus rhombeatus</i>)	>6.5	277	Squawfish, Sacramento (<i>Ptychocheilus grandis</i>)		9
Amphibia			278	Sturgeon, white (<i>Acipenser transmontanus</i>)		50
199	Coecilian, S. American (<i>Siphonops annulatus</i>)	9.5	279	Sunfish, green (<i>Lepomis cyanellus</i>)*	2.2	9
200	Congo "eel" (<i>Amphiuma means</i>)	26.8	280	Tautog (<i>Tautoga onitis</i>)		8
201	Frog, African speckled (<i>Rana adspersa</i>)	5.4 ¹	281	Trout, brown (<i>Salmo trutta</i>)*	3.2	18
202	Frog, bull (<i>R. catesbeiana</i>)	>15.6	282	Trout, lake (<i>Salvelinus namaycush</i>)*	7.6	41
203	Frog, clawed (<i>Xenopus laevis</i>)	15	283	Trout, rainbow (<i>Salmo irideus</i>)		>3.9
204	Frog, green (<i>Rana clamitans</i>)	>10.1	284	Tuna, bluefin (<i>Thunnus thynnus</i>)*		7
205	Frog, leopard (<i>R. pipiens</i>)	>5.9	285	Walleye, yellow (<i>Stizostedion vitreum</i>)*	4.8	18
206	Frog, palaearctic grass (<i>R. temporaria</i>)	>4.3	286	Whitefish, lake (<i>Coregonus clupeaformis</i>)*	5.3	26
207	Frog, palaearctic water (<i>R. esculenta</i>)	>5.1	Invertebrata			
208	Frog, red-spotted (<i>Leptodactylus pentadactylus</i>)	15.7	Echinodermata		Maximum yr	
209	Frog, S. African (<i>Phrynomerus bifasciatus</i>)	>0.4	Asterioidea			
210	Hellbender (<i>Cryptobranchus alleganiensis</i>)	>28.5	287	Starfish (<i>Asterias rubens</i>)		>5
211	Mudpuppy, N. American (<i>Necturus maculosus</i>)	>8.8	Holothuroidea			
212	Newt, California (<i>Taricha torosus</i>)	21	288	Sea cucumber (<i>Cucumaria plani</i>)		>10
213	Newt, common (<i>Triturus viridescens</i>)	2.9	Mollusca			
214	Newt, European crested (<i>T. cristatus</i>)	17	Pelecypoda			
215	Newt, Pyrenean (<i>Euproctus asper</i>)	>7	289	Clam, giant (<i>Tridacna gigas</i>)		60-100 ¹
216	Proteus, European (<i>Proteus anguinus</i>)	15	290	Mussel, edible (<i>Mytilus edulis</i>)		<1
217	Salamander, Asiatic (<i>Megalobatrachus maximus</i>)	55	291	Mussel, fresh-water (<i>Margaritana margaritifera</i>)		100 ¹
218	Salamander, European (<i>Salamandra atra</i>)	3	292	Mussel, fresh-water (<i>Pisidium</i> spp)		2-4
219	Salamander, long-tailed (<i>Eurycea lucifuga</i>)	>1	293	Mussel, fresh-water (<i>Unio crassus</i>)		12
220	Salamander, spotted (<i>Ambystoma maculatum</i>)	25	294	Mussel, pearl (<i>Pinctada</i> spp)		8
221	Salamander, tiger (<i>A. tigrinum</i>)	11	295	Mussel, pond (<i>Anodonta fluviatilis</i>)		10
222	Siren, N. American (<i>Siren lacertina</i>)	25.5	296	Oyster (<i>Ostrea edulis</i>)		10
223	Toad, American (<i>Bufo americanus</i>)	12-23	297	Scallop (<i>Pecten jessoensis</i>)		7
224	Toad, Cuban (<i>B. peltacephalus</i>)	13	298	Shell, fingernail (<i>Musculium</i> spp)		2-4
225	Toad, Degen's (<i>B. vittatus</i>)	2.4	299	Shell, fingernail (<i>Sphaerium</i> spp)		2-4
226	Toad, giant (<i>B. alvarius</i>)	2	300	Shipworm (<i>Teredo</i> spp)		<1
227	Toad, northwestern (<i>B. boreas</i>)	6	Gastropoda			
228	Toad, Surinam (<i>Pipa pipa</i>)	>7.8 ²	301	Opisthobranch (<i>Gasteropteron meckelii</i>)		1
229	Tree-frog, Florida (<i>Hyla gratiosa</i>)	5.9	302	Periwinkle (<i>Littorina littorea</i>)		20
230	Tree-frog, giant (<i>H. septentrionalis</i>)	6.75	303	Prosobranch, freshwater (<i>Neritina</i> spp)		5
231	Tree-frog, palaearctic (<i>H. arborea</i>)	14	304	Sea hare (<i>Aplysia</i> spp)		1
232	Tree-frog, rain (<i>H. versicolor</i>)	6.7	305	Shell, moon (<i>Lunatia heros</i>)		30
233	Tree-frog, S. American (<i>H. raddiana</i>)	2.3	306	Slug (<i>Milax marginatus</i>)		2-3
Pisces			307	Slug (<i>Limax</i> spp)		1-3
234	Anchovy, northern (<i>Engraulis mordax</i>)	7	308	Slug, marine (<i>Doris</i> spp)		1
235	Bass, large-mouth (<i>Micropterus salmoides</i>)	11 ²	309	Slug, marine nudibranch (<i>Aeolidia</i> spp)		1
236	Bass, small-mouth (<i>M. dolomieu</i>)	11 ²	310	Slug, marine nudibranch (<i>Janolus instans</i>)		1
237	Bass, striped (<i>Roccus saxatilis</i>)*	24	311	Snail, edible (<i>Helix pomatia</i>)		18 ²
238	Bullhead, black (<i>Ameiurus melas</i>)*	9	312	Snail, fresh-water (<i>Ancylus</i> spp)		4-5
239	Carp, mirror (<i>Cyprinus carpio</i> var.)	47 ²	313	Snail, fresh-water (<i>Lymnaea</i> spp)		4-5
240	Carp, Prussian (<i>C. carpio</i>)	<6.5	314	Snail, fresh-water (<i>Planorbis</i> spp)		4-5
241	Catfish, flathead (<i>Pilodictis olivaris</i>)*	15	315	Snail, land (<i>Campylaea cingulata</i>)		4-5

/1/ Reported as not authenticated. /2/ Still alive at time of report. /3/ May be *Testudo radiata* from Madagascar.

152. LIFE SPAN: ANIMALS (Concluded)

Species		Maximum yr	Species		Maximum yr
Invertebrata (continued)			Invertebrata (concluded)		
Gastropoda (concluded)			Nematoda (concluded)		
316	Snail, land (<i>Helicigona</i> , <i>Arianta arbustorum</i>)	4-5	387	Hookworm (<i>Necator americanus</i>)	12
317	Snail, pond (<i>Viviparus coniectus</i>)	5	388	Immitis (<i>Dirofilaria</i> spp) ¹⁵	7
318	Snail, pulmonate (<i>Paludina</i> spp)	8-10	389	Kidneyworm, giant, dog (<i>Diectophyme renale</i>)	2
Decapoda			390	Lungworm, dog (<i>Oslerus osleri</i>)	0.4
319	Squid (<i>Loligo pealei</i>)	>2	391	Oxyurid, mice (<i>Heterakis spumosa</i>)	0.8
320	Squid (<i>L. vulgaris</i>)	>2	392	Nematode (<i>Enterobius vermicularis</i>)	0.1
321	Squid, giant (<i>Architeuthis</i> spp)	10	393	Nematode (<i>Haemonchus contortus</i>)	1
Amphineura			394	Nematode (<i>Trichostrongylus</i> sp)	8.5
322	Chiton, coat-of-mail shell (<i>Chaetopleura apiculata</i>)	4	395	Nematode (<i>Anguina tritica</i>) ¹⁶	27
Arthropoda			396	Nematode (<i>Ditylenchus dipsaci</i>) ¹⁶	9
Insecta			397	Nematode (<i>Pratylenchus pratensis</i>) ¹⁷	11
323	Ant (<i>Lasius</i> sp)	10-15	398	Nematode (<i>Tylenchus polyhyppus</i>)	39
324	Ant (<i>Formica fusca</i>) ⁴	13	399	Nematode, free-living (<i>Cephalobus dubius</i>)	0.4
325	Ant, red (<i>F. sanguinea</i>) ⁵	5	400	Nematode, free-living (<i>Diplogaster robustus</i>)	0.04
326	Aphid (<i>Aphis evonymi</i>)	0.08	401	Nematode, free-living (<i>Pristionchus aerivora</i>)	0.1
327	Bedbug (<i>Cimex lectularius</i>) ⁶	0.5	402	Nematode, free-living (<i>Rhabditis elegans</i>)	0.03
328	Bee, honey (<i>Apis mellifera</i>) ⁷	<0.5	403	Nematode, trichinella (<i>Trichinella spiralis</i>) ¹⁸	0.4
329	Bee, honey (<i>A. mellifera</i>) ⁴	5	404	Nematode, trichinella cysts (<i>T. spiralis</i>)	30
330	Bee, honey (<i>A. mellifera</i>) ⁵	0.8	Acanthocephala		
331	Beetle (<i>Cybister roeselii</i>)	0.02	405	Acanthocephalan, pig (<i>Macracanthorhynchus hiriduncus</i>)	1
332	Beetle, buprestid (<i>Eurythra</i> spp)	27 ¹	Gastrotricha		
333	Beetle, capricorn (<i>Hylotrupes bajulus</i>)	98	406	Gastrotrich (<i>Lepidodermella squamatum</i>)	0.05
334	Beetle, chrysomelid (<i>Timarsha</i> spp)	5	Rotifera		
335	Beetle, darkling (<i>Akis lusitanica</i>)	7	407	(<i>Adinota barbata</i>)	0.06
336	Beetle, darkling (<i>Blaps</i> spp)	6	408	(<i>A. vaga</i>)	0.06
337	Beetle, flour (<i>Tribolium</i> sp)	3	409	(<i>Asplanchna sieboldii</i>)	0.05
338	Beetle, ground (<i>Carabidae</i>) ^{8, 9}	7-11	410	(<i>Brachionus pala</i>)	0.05
339	Beetle, June (<i>Melolontha vulgaris</i>) ¹⁰	4-5	411	(<i>Cupelopagis vorax</i>)	0.1
340	Beetle, long-horned (<i>Cerambycidae</i>) ⁹	45	412	(<i>Ephines brachionus</i>)	0.04
341	Beetle, stag (<i>Lucanus cervus</i>)	6	413	(<i>E. senta</i>)	0.02
342	Beetle, stag (<i>L. cervus</i>) ¹⁰	0.02	414	(<i>Euchlanis dilatata</i>)	0.06
343	Beetle, wood-boring (<i>Buprestis splendens</i>)	30	415	(<i>E. triquetra</i>)	0.06
344	Booklouse (<i>Liposcelis</i> sp)	1.04	416	(<i>Floscularia conifera</i>)	0.05
345	Cerambycid (<i>Cerambyx</i> sp) ¹⁰	45	417	(<i>Habrotricha constricta</i>)	0.09
346	Cerambycid (<i>Hesperophanes mixtus</i>) ¹⁰	9-10	418	(<i>Keratella aculeata</i>)	0.08
347	Cerambycid (<i>Stromatium fulvum</i>)	11	419	(<i>Lecane inermis</i>)	0.03
348	Chafer, rose (<i>Cetonia aurata</i>)	6	420	(<i>Macrotrachela quadricornifera</i>)	0.1
349	Cicada, periodical (<i>Magicicada septendecim</i>)	17	421	(<i>Mniobia russeola</i>)	0.08
350	Cricket (<i>Gryllotalpa</i> sp)	1	422	(<i>Philodina citrina</i>)	0.06
351	Earwig (<i>Forficula auricularia</i>)	5	423	(<i>P. magalotrocha</i>)	0.04
352	Fly, fruit (<i>Drosophila melanogaster</i>) ¹¹	0.1	424	(<i>P. roseola</i>)	0.02
353	Fly, fruit (<i>D. melanogaster</i>) ¹²	0.05	425	(<i>Prales sordida</i>)	0.02
354	Fly, house (<i>Musca domestica</i>)	0.2	426	(<i>Proales decipiens</i>)	0.03
355	Fly, syrphid (<i>Eristalis tenax</i>)	0.09	427	(<i>Rotaria macrura</i>)	0.1
356	Grasshopper (<i>Melanoplus differentialis</i>)	0.2	428	(<i>R. rotatoria</i>)	0.1
357	Grasshopper, short-horned (<i>Acrididae</i>) ⁹	<1	Platyhelminthes		
358	Maggot, apple (<i>Rhagoletis pomonella</i>)	0.3	Turbellaria		
359	Mantis, praying (<i>Mantis religiosa</i>)	8	429	Flatworm (<i>Planaria torva</i>)	1.1
360	Mosquito (<i>Aedes geniculatus</i>)	1.5	430	Worm, polyclad (<i>Yungia aurantiaca</i>)	1
361	Roach, American (<i>Periplaneta americana</i>)	4.6	Cestoda		
362	Roach, German (<i>Blattella germanica</i>)	1.3	431	Tapeworm, beef (<i>Taenia saginata</i>) ¹⁹	0.09
363	Silverfish (<i>Lepisma saccharina</i>)	2	432	Tapeworm, fish (<i>Diphyllbothrium latum</i>) ¹⁹	0.09
Chilopoda			433	Tapeworm, sheep (<i>Moniezia expansa</i>)	0.1
364	Centipede, garden (<i>Scutigera immaculata</i>)	0.9-1	Coelenterata		
365	Stone-crawler (<i>Lithobius forficatus</i>)	3	Hydrozoa		
Arachnida			434	Hydra, fresh-water (<i>Hydra grisea</i>)	1-2
366	Spider, bird- (<i>Avicularis avicularis</i>)	15	Scyphozoa		
367	Spider, house (<i>Tegenaria civilis</i>)	0.01	435	Jelly-fish (<i>Cotylorhiza tuberculata</i>)	0.5-0.6
368	Spider, purse-web (<i>Atypus piceus</i>)	713	Anthozoa		
369	Spider, British trapdoor (<i>A. sp</i>)	0.02	436	Coral (<i>Favites</i> spp)	>22-28
370	Spider, American tarantula (<i>Mygale hantzii</i>)	0.02	437	Coral (<i>Goniastrea</i> spp)	>22-28
371	Tick, Rocky Mt. wood (<i>Dermacentor andersoni</i>)	3-4	438	Coral (<i>Montastrea</i> spp)	>22-28
Crustacea			439	Coral (<i>Pocillopora</i> spp)	>22-28
372	Crab, fresh-water (<i>Astacus fluviatilis</i>)	30	440	Coral, solitary (<i>Flabellum</i> sp)	24
373	Crustacea, fresh-water (spp)	1-1.5	441	Sea-anemone (<i>Actinia equina</i>)	67
374	Flea, water (<i>Daphnia</i> sp) ¹⁴	7	442	Sea-anemone (<i>Cerianthus membranaceus</i>)	40
375	Flea, water (<i>D. magna</i>)	0.2	443	Sea-anemone (<i>Heliactis bellis</i>)	20
376	Flea, water cladocera (<i>D. longispina</i>)	0.1	444	Sea-anemone (<i>Sagartia troglodytes</i>)	50
377	Lobster, European (<i>Homarus gammarus</i>)	33	Porifera		
378	Ostracod (<i>Cyprinus incongruens</i>)	0.2-0.3	445	Demospongiae	
379	Ostracod (<i>Herpetocypris strigata</i>)	1.1	446	Sponge, commercial (<i>Hippospongia</i> sp)	50
Annelida			447	Sponge, siliceous (<i>Axinella</i> sp)	4
Polychaeta			448	Calcispongiae	
380	Sandworm (<i>Platynereis dumerilii</i>)	<1	449	Sponge, calcareous (<i>Scypha capillata</i>)	0.2
Oligochaeta			Protozoa		
381	Earthworm (<i>Lumbricus terrestris</i>)	10	Sarcodina		
Hirudinea			448	(<i>Elphidium crispum</i>)	2-4
382	Leech (<i>Hirudo medicinalis</i>)	27	Flagellata		
Nemathelminthes			449	(<i>Mastigamoeba</i> sp) ²⁰	20
383	Eyeworm (<i>Loa loa</i>)	15	450	(<i>Oikomonas</i> sp) ²⁰	20
384	Filaria (<i>Wuchereria bancrofti</i>)	17	Ciliata		
385	Hookworm (<i>Ancylostoma duodenale</i>)	7	451	(<i>Didinium nastum</i>) ²⁰	10
386	Hookworm (<i>A. caninum</i>) ¹⁵	2			

/1/ Reported as not authenticated. /4/ Queen. /5/ Worker. /6/ Unfed female. /7/ Drone. /8/ Including developmental period. /9/ Family name. /10/ Larva. /11/ Normal strain. /12/ Vestigial strain. /13/ Three years as adult. /14/ Winter eggs. /15/ In dog. /16/ Desiccated in dry wheat gall. /17/ Desiccated in fig roots. /18/ Adults in guinea pigs. /19/ In man. /20/ Cysts.

153. LIFE SPAN: TREES AND SHRUBS

Life span refers to age at natural death. There is great variation from the approximate ages given in table, and some individuals of each species live much longer than indicated.

Species	Life Span yr	Species	Life Span yr
Forest Trees, U.S.A.		Forest Trees, U.S.A. (concluded)	
1 Alaska-cedar (<i>Chamaecyparis nootkatensis</i>)	300-600	86 Persimmon (<i>Diospyros virginiana</i>)	60-80
2 Alder, red (<i>Alnus rubra</i>)	60-100	87 Pine, digger (<i>Pinus sabiniana</i>)	80-150
3 Ash, blue (<i>Fraxinus quadrangulata</i>)	200-300	88 Pine, eastern white (<i>P. strobus</i>)	300-500
4 Ash, Oregon (<i>F. latifolia</i>)	150-250	89 Pine, jack (<i>P. banksiana</i>)	80-150
5 Ash, white (<i>F. americana</i>)	260-300	90 Pine, jeffrey (<i>P. jeffreyi</i>)	300-500
6 Aspen, bigtooth (<i>Populus grandidentata</i>)	70-100	91 Pine, knobcone (<i>P. attenuata</i>)	100-150
7 Aspen, quaking (<i>P. tremuloides</i>)	70-100	92 Pine, limber (<i>P. flexilis</i>)	200-400
8 Baldcypress (<i>Taxodium distichum</i>)	600-1200	93 Pine, loblolly (<i>P. taeda</i>)	150-250
9 Basswood, American (<i>Tilia americana</i>)	100-140	94 Pine, lodgepole (<i>P. contorta</i>)	120-300
10 Beech, American (<i>Fagus grandifolia</i>)	300-400	95 Pine, longleaf (<i>P. palustris</i>)	300-400
11 Birch, gray (<i>Betula populifolia</i>)	50	96 Pine, pitch (<i>P. rigida</i>)	100-200
12 Birch, paper (<i>B. papyrifera</i>)	80-100	97 Pine, ponderosa (<i>P. ponderosa</i>)	300-500
13 Birch, sweet (<i>B. lenta</i>)	150-250	98 Pine, red (<i>P. resinosa</i>)	200-350
14 Birch, yellow (<i>B. alleghaniensis</i>)	150-300	99 Pine, shortleaf (<i>P. echinata</i>)	200-300
15 Buckeye, yellow (<i>Aesculus octandra</i>)	60-80	100 Pine, slash (<i>P. elliotii</i>)	150-250
16 Buckthorn, cascara (<i>Rhamnus purshiana</i>)	40-50	101 Pine, spruce (<i>P. glabra</i>)	75-150
17 Butternut (<i>Juglans cinerea</i>)	80	102 Pine, sugar (<i>P. lambertiana</i>)	300-600
18 California-laurel (<i>Umbellularia californica</i>)	200	103 Pine, Virginia (<i>P. virginiana</i>)	100-200
19 Catalpa, northern (<i>Catalpa speciosa</i>)	100	104 Pine, western white (<i>P. monticola</i>)	200-500
20 Cherry, black (<i>Prunus serotina</i>)	100-200	105 Pinyon (<i>P. edulis</i>)	150-400
21 Chestnut, American (<i>Castanea dentata</i>)	100-300	106 Pinyon, singleleaf (<i>P. monophylla</i>)	150-225
22 Chinkapin, golden (<i>Castanopsis chrysophylla</i>)	200-400	107 Poplar, balsam (<i>Populus balsamifera</i>)	100-150
23 Cottonwood, black (<i>Populus trichocarpa</i>)	150-200	108 Port-Orford-cedar (<i>Chamaecyparis lawsoniana</i>)	300-500
24 Cottonwood, eastern (<i>P. deltoides</i>)	60-100	109 Redcedar, eastern (<i>Juniperus virginiana</i>)	150-300
25 Cottonwood, plains (<i>P. sargentii</i>)	50-90	110 Redcedar, western (<i>Thuja plicata</i>)	500-800
26 Cucumbertree (<i>Magnolia acuminata</i>)	80-250	111 Redwood (<i>Sequoia sempervirens</i>)	800-1500
27 Cypress, Arizona (<i>Cupressus arizonica</i>)	100-300	112 Sassafras (<i>Sassafras albidum</i>)	100-500
28 Dogwood, Pacific (<i>Cornus nuttallii</i>)	125	113 Sequoia, giant (<i>Sequoia gigantea</i>)	2000-3000
29 Douglas-fir (<i>Pseudotsuga menziesii</i>)	300-700	114 Spruce, black (<i>Picea mariana</i>)	150-250
30 Elm, American (<i>Ulmus americana</i>)	150-300	115 Spruce, blue (<i>P. pungens</i>)	150-350
31 Elm, rock (<i>U. thomasi</i>)	250	116 Spruce, Engelmann (<i>P. engelmannii</i>)	200-500
32 Elm, slippery (<i>U. rubra</i>)	300	117 Spruce, red (<i>P. rubens</i>)	200-300
33 Fir, alpine (<i>Abies lasiocarpa</i>)	150-200	118 Spruce, Sitka (<i>P. sitchensis</i>)	400-750
34 Fir, balsam (<i>A. balsamea</i>)	100-150	119 Spruce, white (<i>P. glauca</i>)	150-350
35 Fir, California red (<i>A. magnifica</i>)	250-400	120 Sweetgum (<i>Liquidambar styraciflua</i>)	200-300
36 Fir, grand (<i>A. grandis</i>)	200-400	121 Sycamore, American (<i>Platanus occidentalis</i>)	250-500
37 Fir, noble (<i>A. procera</i>)	300-500	122 Tamarack (<i>Larix laricina</i>)	100-200
38 Fir, Pacific silver (<i>A. amabilis</i>)	250-300	123 Tanoak (<i>Lithocarpus densiflora</i>)	150-300
39 Fir, white (<i>A. concolor</i>)	150-400	124 Walnut, black (<i>Juglans nigra</i>)	150-250
40 Hackberry (<i>Celtis occidentalis</i>)	75-150	125 White-cedar, Atlantic (<i>Chamaecyparis thyoides</i>)	100-200
41 Hemlock, eastern (<i>Tsuga canadensis</i>)	300-600	126 White-cedar, northern (<i>Thuja occidentalis</i>)	300-400
42 Hemlock, mountain (<i>T. mertensiana</i>)	200-500	127 Willow, black (<i>Salix nigra</i>)	50-125
43 Hemlock, western (<i>T. heterophylla</i>)	300-600	128 Willow, peachleaf (<i>S. amygdaloides</i>)	50-100
44 Hickory, bitternut (<i>Carya cordiformis</i>)	175	129 Yellow-poplar (<i>Liriodendron tulipifera</i>)	200-250
45 Hickory, mockernut (<i>C. tomentosa</i>)	200-300	130 Yew, Pacific (<i>Taxus brevifolia</i>)	250-350
46 Hickory, pignut (<i>C. glabra</i>)	200-300	Various Trees and Shrubs	
47 Hickory, shagbark (<i>C. ovata</i>)	250-300	131 Alder, European (<i>Alnus glutinosa</i>)	100
48 Hickory, shellbark (<i>C. laciniata</i>)	350	132 Barberry, European (<i>Berberis vulgaris</i>)	25
49 Hickory, water (<i>C. aquatica</i>)	125	133 Beech, European (<i>Fagus sylvatica</i>)	600
50 Holly, American (<i>Ilex opaca</i>)	100-150	134 Birch, European (<i>Betula pubescens</i>)	125
51 Honeylocust (<i>Gleditsia triacanthos</i>)	120	135 Buckthorn, European (<i>Rhamnus cathartica</i>)	100
52 Insect-cedar (<i>Libocedrus decurrens</i>)	300-400	136 Catalpa, southern (<i>Catalpa bignonioides</i>)	60
53 Juniper, alligator (<i>Juniperus deppeana</i>)	300-500	137 Cedar-of-Lebanon (<i>Cedrus libanensis</i>)	1200
54 Juniper, Rocky Mt. (<i>J. scopulorum</i>)	100-300	138 Cotoneaster, European (<i>Cotoneaster integerrima</i>)	15
55 Juniper, Utah (<i>J. osteosperma</i>)	150-300	139 Cypress, Italian (<i>Cupressus sempervirens</i>)	2000
56 Juniper, western (<i>J. occidentalis</i>)	300	140 Dogwood, bloodtwig (<i>Cornus sanguinea</i>)	50
57 Larch, western (<i>Larix occidentalis</i>)	300-600	141 Dogwood, Cornelian (<i>C. mas</i>)	300
58 Locust, black (<i>Robinia pseudoacacia</i>)	60-100	142 Elder, European (<i>Sambucus nigra</i>)	100
59 Magnolia, southern (<i>Magnolia grandiflora</i>)	80-120	143 Elder, European red (<i>S. racemosa</i>)	20
60 Maple, bigleaf (<i>Acer macrophyllum</i>)	150-300	144 Fig, religious (<i>Ficus religiosa</i>)	2000
61 Maple, red (<i>A. rubrum</i>)	80-250	145 Filbert, European (<i>Corylus avellana</i>)	150
62 Maple, silver (<i>A. saccharinum</i>)	50-125	146 Filbert, Turkish (<i>C. colurna</i>)	100
63 Maple, sugar (<i>A. saccharum</i>)	200-300	147 Hawthorn, English (<i>Crataegus oxyacantha</i>)	400
64 Mulberry, red (<i>Morus rubra</i>)	125	148 Honeysuckle, woodbine (<i>Lonicera periclymenum</i>)	40
65 Oak, black (<i>Quercus velutina</i>)	150-200	149 Hophornbeam, European (<i>Ostrya carpinifolia</i>)	100
66 Oak, blackjack (<i>Q. marilandica</i>)	100	150 Hornbeam, American (<i>Carpinus caroliniana</i>)	100
67 Oak, bur (<i>Q. macrocarpa</i>)	200-400	151 Hornbeam, European (<i>C. betulus</i>)	250
68 Oak, Calif. black (<i>Q. kelloggii</i>)	175-300	152 Juniper, common (<i>Juniperus communis</i>)	2000
69 Oak, Calif. live (<i>Q. agrifolia</i>)	150	153 Maple, Norway (<i>Acer platanoides</i>)	400
70 Oak, Calif. white (<i>Q. lobata</i>)	200-300	154 Mountain-ash, European (<i>Sorbus aucuparia</i>)	80
71 Oak, canyon live (<i>Q. chrysolepis</i>)	200-300	155 Pine, Austrian (<i>Pinus nigra</i>)	600
72 Oak, chestnut (<i>Q. prinus</i>)	300-400	156 Pine, Scotch (<i>P. sylvestris</i>)	500
73 Oak, live (<i>Q. virginiana</i>)	200-300	157 Pine, Swiss stone (<i>P. cembra</i>)	1200
74 Oak, northern red (<i>Q. rubra</i>)	200-400	158 Poplar, white (<i>Populus alba</i>)	300
75 Oak, overcup (<i>Q. lyrata</i>)	300-400	159 Rhododendron, garland (<i>Rhododendron hirsutum</i>)	50
76 Oak, pin (<i>Q. palustris</i>)	125-150	160 Rhododendron, rock (<i>R. ferrugineum</i>)	40
77 Oak, post (<i>Q. stellata</i>)	250	161 Service-tree (<i>Sorbus domestica</i>)	140
78 Oak, scarlet (<i>Q. coccinea</i>)	150	162 Service-tree (<i>S. torminalis</i>)	230
79 Oak, southern red (<i>Q. falcata</i>)	200-275	163 Spruce, Norway (<i>Picea abies</i>)	400
80 Oak, swamp chestnut (<i>Q. michauxii</i>)	100-200	164 Walnut, English (<i>Juglans regia</i>)	300
81 Oak, swamp white (<i>Q. bicolor</i>)	300	165 Willow, myrtle (<i>Salix myrsinites</i>)	100
82 Oak, water (<i>Q. nigra</i>)	175	166 Willow, white (<i>S. alba</i>)	150
83 Oak, white (<i>Q. alba</i>)	300-600	167 Wisteria, Chinese (<i>Wisteria sinensis</i>)	60
84 Osage-orange (<i>Maclura pomifera</i>)	75-100	168 Yew, English (<i>Taxus baccata</i>)	900
85 Pecan (<i>Carya illinoensis</i>)	300		

154. LIFE SPAN: POLLEN

Field and Forage Crops						Ornamental Plants (concluded)					
1	Barley (<i>Hordeum vulgare</i>)	2.2 ³		19	41	36	Day lily (<i>Emmerocallis flava</i>)	17.5-21 ⁴	0 ⁷	29	
2	Bluegrass (<i>Poa compressa</i>)	17.5-21 ⁴		1		37	Deutzia (<i>Deutzia scabra</i>)	24 ⁵	Air dry	20	
3	Clover (<i>Trifolium hybridum</i>)	24 ⁵	Air dry	12		38	Gladiolus (<i>Gladiolus hybrida</i>)	10	50	100	30 ¹³
4	Corn (<i>Zea mays</i>)	5-10	50-70	3	70 ⁶	39	Iris (<i>Iris pseudocorus</i>)	24 ⁵	Air dry	28	
5	Cotton (<i>Gossypium pima</i> var.)	4.4-10		4 ³	64 ⁶	40	Lily (<i>Lilium</i> spp)	10	35-50	425	>45
6	Foxtail-grass (<i>Alopecurus pratensis</i>)	17.5-21 ⁴		2		41	Mockorange (<i>Philadelphus floribundus</i>)	24 ⁵	Air dry	32	
7	Hemp (<i>Cannabis sativa</i>)	17.5-21 ⁴	0 ⁷	8		42	Narcissus (<i>Narcissus poeticus</i>)	24 ⁵	Air dry	72	
8	Orchardgrass (<i>Dactylis glomerata</i>)	17.5-21 ⁴	30	3		43	Narcissus (<i>N. pseudonarcissus</i>)	24 ⁵	Air dry	80	
9	Rye (<i>Secale cereale</i>)	17.5-21 ⁴		0.5		44	Nasturtium (<i>Tropaeolum majus</i>)	17.5-21 ⁴	0 ⁷	88	
10	Ryegrass (<i>Lolium perenne</i>)	17.5-21 ⁴		1		45	Nicotiana (<i>Nicotiana sylvestris</i>)			205 ¹⁴	
11	Sweetclover (<i>Melilotus alba</i>)	17.5-21 ⁴	30	96		46	Poppy (<i>Eschscholtzia californica</i>)	17-22	0 ⁹	19	
Fruit and Nut Crops						47	Poppy (<i>Papaver rhoeas</i>)	17.5-21 ⁴	0 ⁷	97	
12	Almond (<i>Prunus amygdalus</i>)	-18		1130	24	48	Primrose (<i>Oenothera biennis</i>)	17.5-21 ⁴	Air dry	8	
13	Apple (<i>Pyrus malus</i>)	2-8	50	1460	20	49	Primrose (<i>Primula elatior</i>)	17.5-21 ⁴	0 ⁷	180	
14	Apricot (<i>Prunus armeniaca</i>)	2-8	50	915	25	50	Rhododendron (<i>Rhododendron</i> spp)	24 ⁵	Air dry	42	
15	Avocado (<i>Persea americana</i>) ⁸	15	0 ⁹	155		51	Snapdragon (<i>Antirrhinum majus</i>)	10-22		670	50 ¹⁵
16	Cherry, sour (<i>Prunus cerasus</i>)	2-8	50	1460	20	52	Stock (<i>Matthiola</i> spp)	5-10	0 ⁷	64	20
17	Cherry, sweet (<i>P. avium</i>)	-18		745	26	53	Sweetpea (<i>Lathyrus odoratus</i>)	24 ⁵	Air dry	23 ⁶	
18	Date (<i>Phoenix dactylifera</i>)	1.1 ¹⁰		275	87 ^{6,11}	54	Tulip (<i>Tulipa gesneriana</i>)	17.5-21 ⁴	30	110	
19	Filbert (<i>Corylus avellana</i>)	17.5-21 ⁴	0 ⁷	65		55	Violet (<i>Viola odorata</i>)	17.5-21 ⁴	0 ⁷	235	
20	Grape (<i>Vitis</i> spp) ⁸	-12	28	1460	6-21	56	Waterlily (<i>Nymphaea alba</i>)	17.5-21 ⁴	0 ⁷	35	
21	Grapefruit (<i>Citrus paradisi</i>)	10 ¹²		42	50	Trees					
22	Papaya (<i>Carica papaya</i>)	1.1	10	150	45	57	Basswood (<i>Tilia platyphyllos</i>)	17.5-21 ⁴	0 ⁷	16	
23	Peach (<i>Prunus persica</i>)	2-8	50	1100	1-20	58	Beech (<i>Fagus sylvatica</i>)	24 ⁵	Air dry	41	
24	Pear (<i>Pyrus communis</i>)	2-8	50	1280	20	59	Birch (<i>Betula verrucosa</i>)	24 ⁵		16	20
25	Pecan (<i>Carya illinoensis</i>)	5		4	40	60	Cinchona (<i>Cinchona hybrida</i>)	10	38	145	23 ¹⁶
26	Pistachio (<i>Pistacia atlantica</i>)	2.2	25	550	30	61	Ginkgo (<i>Ginkgo biloba</i>)	7	0 ⁹	365 ⁶	
27	Plum (<i>Prunus domestica</i>)	2-8	50	1280	20	62	Goldenchaintree (<i>Laburnum anagyroides</i>)	17.5-21 ⁴	30	260	
28	Quince (<i>Cydonia oblonga</i>)	2.2	25	550	54	63	Locust (<i>Robinia pseudoacacia</i>)	24 ⁵	Air dry	30	
29	Strawberry (<i>Fragaria</i> spp)	24 ⁵	Air dry	>16		64	Maple (<i>Acer</i> sp)	17-22	Air dry	18	
30	Walnut (<i>Juglans sieboldiana</i>)	0	40-60	255	12	65	Oak (<i>Quercus coccinea</i>)	2	25-35	365	46
Ornamental Plants						66	Pine, red (<i>Pinus resinosa</i>) ¹⁷	0-4	50	415	92 ¹⁸
31	Azalea (<i>Rhododendron molle</i>)	17.5-21 ⁴	30	175		67	Pine, Scotch (<i>P. sylvestris</i>)	17.5-21 ⁴	0 ⁷	280	
32	Bellflower (<i>Campanula persicifolia</i>)	24 ⁵	Air dry	21		68	Rubber-tree (<i>Hevea</i> sp)	6	67-80	19	
33	Buttercup (<i>Ranunculus acris</i>)	17.5-21 ⁴	0 ⁷	49		69	Spruce (<i>Picea glauca</i>)	2 ¹⁹	10-75	365	60
34	Camellia (<i>Camellia japonica</i>)	24 ⁵	Air dry	60		70	Tung oil tree (<i>Aleurites fordii</i>)	5 ³		24	>40
35	Cyclamen (<i>Cyclamen persicum</i>)	17-22	0 ⁹	185		71	Willow (<i>Salix</i> spp)	-3 to 3		50	2-10

/1/ Demonstrated viability in storage. /2/ Values are number of pollen grains germinating, expressed as percentages of total pollen grains tested at age specified under life span, unless otherwise indicated. Where no value is given data are not available. /3/ Flower spike or flower cut in early morning and kept under refrigeration. /4/ Average temperature for tests conducted during winter was 17.5°C; during summer, 21°C. /5/ Storage at room temperature. /6/ Data recorded on basis of seed or fruit set. /7/ Storage over concentrated sulfuric acid in desiccator. /8/ Horticultural varieties. /9/ Storage over calcium chloride in desiccator. /10/ Pollen stored in sealed or stoppered vial. /11/ At end of 365 days, 69%. /12/ Pollen stored under reduced pressure in evacuated and sealed tubes. /13/ Data recorded on basis of seed set per capsule. /14/ Sealed in ampules in vacuum or CO₂. /15/ Germination weak; no fruit set after storage of 161 days of 0°C. /16/ At end of 371 days, 6%. /17/ Data also applicable to white pine (*P. strobus*). /18/ Humidified at 75% relative humidity and 4°C for 12 hours after storage. /19/ Stored in darkness.

155. TEMPERATURE EFFECT ON LIFE SPAN: SEEDS
Seeds stored in sealed containers.

Species	Moisture Content ¹	Median Life Span ²		Maximum Life Span ³		Median Life Span ²		Maximum Life Span ³	
		yr at 24°C ⁴		yr at 5°C		yr at -4°C			
	%								
1	Ash (<i>Fraxinus excelsior</i>)	7	1	<2	7	<8			
2	Ash (<i>F. pennsylvanica</i>)	7	2	5	8	<9			
3	Aster (<i>Callistephus chinensis</i>)	7	2	3	10	12			
4	Carrot (<i>Daucus carota</i>)	5	16	>20					
5	Cauliflower (<i>Brassica oleracea botrytis</i>)	Air dry	>3	8					
6	Cinchona (<i>Cinchona ledgeriana</i>)	6	2	4	7	8			
7	Cotton (<i>Gossypium</i> spp.)	5	1	8	>13	>13			
8	Dandelion (<i>Taraxacum officinale</i>)	6	6	>11	>14	>14			
9	Eggplant (<i>Solanum melongena</i>)	5	18	>20					
10	Elm (<i>Ulmus americana</i>)	7	2	4	8	10			
11	Fir (<i>Abies grandis</i>)	11	<1	<1	1	>10			
12	Fir (<i>A. procera</i>)	11	<1	1	1	>10			
13	Gladiolus (<i>Gladiolus</i> spp)	8	6	10	7	8			
14	Grapefruit (<i>Citrus paradisi</i>)	60	<1	1	1	>1			
	Larkspur (<i>Delphinium</i> spp)								
15	Annual	Air dry	5	9	16	19			
16	Perennial	Air dry	2	3	7	13			
17	Lemon (<i>Citrus limonia</i>)	56	<1	<1	>1	>1			
18	Lettuce (<i>Lactuca sativa</i>)	4	13	15					
19	Lily (<i>Lilium regale</i>)	5	8	11	13	14			
20	Onion (<i>Allium cepa</i>)	6	11	14					
21	Pansy (<i>Viola</i> spp)	4	2	>3	3	4			
22	Peony (<i>Paeonia suffruticosa</i>)	Air dry	<1	<1	3	8			
23	Pepper (<i>Capsicum frutescens</i>)	5	8	12					
24	Pine (<i>Pinus caribaea</i>)	Air dry	4	8	8	>8			
25	Pine (<i>P. echinata</i>)	Air dry	1	2	11	>11			
26	Pine (<i>P. palustris</i>)	Air dry	<1	<1	1	5			
27	Pine (<i>P. taeda</i>)	Air dry	1	2	10	>11			
28	Spruce (<i>Picea abies</i>)	5							
29	Sweetpea (<i>Lathyrus</i> spp)	10	2	4	>3	>3			
30	Tomato (<i>Lycopersicon esculentum</i>)	5	17	>20					
31	Venidium (<i>Venidium</i> spp)	5	>4	>4	>4	>4			
32	Verbena (<i>Verbena teucrioides</i>)	6	3	6	9	13			

/1/ At time of storage. /2/ Years for 50% seed survival. /3/ Maximum life span for a single seed. /4/ Temperature of laboratory, approximately 24°C.

156. FOODS OF PLANT ORIGIN: COMPOSITION

Values are per 100 g of edible portion of fresh, uncooked food, unless otherwise specified. Values based on inadequate evidence are enclosed in parentheses.

Food	Water g	Food Energy Cal	Protein g	Fat g	Carbohydrate Total g	Fiber g	Ash g	Ca mg	Fe mg	P mg	Vita- min A I. U.	Ascor- bic Acid mg	Niacin mg	Ribo- flavin mg	Thia- mine mg
1 Apple (<i>Pyrus malus</i>)	84.1	58	0.3	0.4	14.9	1.0	0.3	6	0.3	10	90	5	0.2	0.03	0.04
2 Apricot (<i>Prunus armeniaca</i>)	85.4	51	1.0	0.1	12.9	0.6	0.6	16	0.5	23	2790	7	0.8	0.05	0.03
3 Asparagus (<i>Asparagus officinalis</i>)	93.0	21	2.2	0.2	3.9	0.7	0.7	21	0.9	62	1000	33	1.4	0.19	0.16
4 Avocado (<i>Persea gratissima</i>)	65.4	245	1.7	26.4	5.1	1.8	1.4	10	0.6	38	290	16	1.1	0.13	0.06
5 Banana (<i>Musa paradisiaca sapientum</i>)	74.8	88	1.2	0.2	23.0	0.6	0.8	28	8	0.6	430	10	0.7	0.05	0.04
6 Barley, pearled, dry (<i>Hordeum vulgare</i>)	11.1	349	8.2	1.0	78.8	0.5	0.9	189	16	(2.0)	(0)	0	3.1	0.08	0.12
7 Bean, common, dried (<i>Phaseolus vulgaris</i>)	12.2	336	23.1	1.7	59.4	3.5	3.6	163	6.9	437	(0)	2	2.5	0.22	0.57
8 Bean, lima, immature (<i>P. lunatus mac.</i>)	66.5	128	7.5	0.8	23.5	1.5	1.7	63	2.3	158	280	32	1.4	0.11	0.21
9 Bean, lima, mature (<i>P. lunatus macrocarpus</i>)	12.6	333	20.7	1.3	61.6	4.3	3.8	68	7.5	381	0	2	2.0	0.18	0.48
10 Bean, snap, green and yellow (<i>P. vulgaris</i>)	88.9	35	2.4	0.2	7.7	1.4	0.8	65	1.1	44	630 ¹	19	0.5	0.11	0.08
11 Beet, garden (<i>Beta vulgaris</i>)	87.6	42	1.6	0.1	9.6	0.9	1.1	27	1.0	43	20	10	0.4	0.05	0.02
12 Blackberry (<i>Rubus spp</i>)	84.8	57	1.2	1.0	12.5	4.2	0.5	32	0.9	32	200	21	0.4	0.04	0.04
13 Blueberry (<i>Vaccinium corymbosum</i>)	83.4	61	0.6	0.6	15.1	1.2	0.3	16	0.8	13	280	16	(0.3)	(0.02)	(0.02)
14 Brazil nut (<i>Bertholletia excelsa</i>)	5.3	646	14.4	65.9	11.0	2.1	3.4	186	3.4	693	Trace				0.86
15 Broccoli (<i>Brassica oleracea botrytis</i>)	89.9	29	3.3	0.2	5.5	1.3	1.1	130	1.3	76	3500	118	1.1	0.2	0.10
16 Brussels sprouts (<i>B. oleracea gemmifera</i>)	84.9	47	4.4	0.5	8.9	1.3	1.3	34	1.3	78	400	94	0.7	0.16	0.08
17 Cabbage (<i>B. oleracea capitata</i>)	92.4	24	1.4	0.2	5.3	1.0	0.8	46	0.5	31	80	50	0.3	0.05	0.06
18 Cantaloupe (<i>Cucumis melo cantalupensis</i>)	94.0	20	0.6	0.2	4.6	0.6	0.6	17	0.4	16	3420	33	0.5	0.04	0.05
19 Carrot (<i>Daucus carota</i>)	88.2	42	1.2	0.3	9.3	1.1	1.0	39	0.8	37	12000		0.5	0.06	0.06
20 Cauliflower (<i>Brassica oleracea botrytis</i>)	91.7	25	2.4	0.2	4.9	0.9	0.8	22	1.1	72	90	69	0.6	0.10	0.11
21 Celery (<i>Apium graveolens</i>)	93.7	18	1.3	0.2	3.7	0.7	1.1	50	0.5	40	0	7	0.4	0.04	0.05
22 Cherry, sour and sweet (<i>Prunus spp</i>)	83.0	61	1.1	0.5	14.8	0.3	0.6	18	0.4	20	620	8	0.4	0.06	0.05
23 Coconut (<i>Cocos nucifera</i>)	46.9	359	3.4	34.7	14.0	3.2	1.0	21	2.0	98	0	2	0.2	0.01	0.10
24 Collard (<i>Brassica acephala</i>)	86.6	40	3.9	0.6	7.2	1.2	1.7	249	1.6	58	6870	100	(2.0)	0.27	0.11
25 Corn, sweet, white and yellow (<i>Zea mays</i>)	73.9	92	3.7	1.2	20.5	0.8	0.7	9	0.5	120	390	12	1.7	0.12	0.15
26 Cranberry (<i>Vaccinium macrocarpon</i>)	87.4	48	0.4	0.7	11.3	1.4	0.2	14	0.6	11	40	12	0.1	(0.02)	(0.03)
27 Cucumber (<i>Cucumis sativus</i>)	96.1	12	0.7	0.1	2.7	0.5	0.4	10	0.32	21	0 ²	8	0.2	0.04	0.03
28 Currant, red (<i>Ribes rubrum</i>)	84.4	55	1.2	0.2	13.6	4.0	0.6	36	0.9	33	120	36			0.04
29 Date, dried (<i>Phoenix dactylifera</i>)	20.0	284	2.2	0.6	75.4	2.4	1.8	72	2.1	60	60	(0)	2.2	0.10	0.09
30 Eggplant (<i>Solanum melongena</i>)	92.7	24	1.1	0.2	5.5	0.9	0.5	15	0.4	37	30	5	0.6	0.05	0.04
31 Fig, dried (<i>Ficus carica</i>)	24.0	270	4.0	1.2	68.4	5.8	2.4	186	3.0	111	80	(0)	1.7	0.12	0.16
32 Grape, American (<i>Vitis spp</i>) ³	81.9	70	1.4	1.4	14.9	0.5	0.4	17	0.6	21	80	4	0.2	0.04	0.06
33 Grapefruit (<i>Citrus paradisi</i>)	88.8	40	0.5	0.2	10.1	0.3	0.4	22	0.2	18	Trace	40	0.2	0.02	0.04
34 Guava (<i>Psidium guajava</i>)	80.6	70	1.0	0.6	17.1	5.5	0.7	30	0.7	29	250	302	1.2	0.04	0.07
35 Kale (<i>Brassica oleracea acephala</i>)	86.6	40	3.9	0.6	7.2	1.2	1.7	225	2.2	62	7540	115	2.0	0.26	0.10
36 Lemon (<i>Citrus limonia</i>)	89.3	32	0.9	0.6	8.7	0.9	0.5	40	0.6	22	0	50	0.1	Trace	0.04
37 Lettuce (<i>Lactuca sativa</i>)	94.8	15	1.2	0.2	2.9	0.6	0.9	22	0.5	25	540	8	0.2	0.08	0.04
38 Mango (<i>Mangifera indica</i>)	81.4	66	0.7	0.2	17.2	1.0	0.5	9	0.2	13	6350	41	0.9	0.06	0.06
39 Mushroom (<i>Agaricus campestris</i>)	91.1	16	2.4	0.3	4.0	0.9	1.1	9	1.0	115	0	5	4.9	0.44	0.10
40 Mustard greens (<i>Brassica japonica</i>)	92.2	22	2.3	0.3	4.0	0.8	1.2	220	2.9	38	6460	102	0.8	0.20	0.09
41 Oats, rolled (<i>Avena sativa</i>)	8.3	390	14.2	7.4	68.2	1.2	1.9	53	4.5	405	(0)	(0)	1.0	0.14	0.60
42 Okra (<i>Hibiscus esculentus</i>)	89.8	32	1.8	0.2	7.4	1.0	0.8	82	0.7	62	740	30	1.1	0.07	0.08
43 Onion, immature, green (<i>Allium cepa</i>)	87.6	35	1.0	0.2	10.6	1.8	0.6	135	0.9	24	(50)	24	(0.2)	(0.04)	(0.03)
44 Onion, mature (<i>A. cepa</i>)	87.5	45	1.4	0.2	10.3	0.8	0.6	32	0.5	44	50	9	0.2	0.04	0.03
45 Orange (<i>Citrus spp</i>)	87.2	45	0.9	0.2	11.2	0.6	0.5	33	0.4	23	(190)	49	0.2	0.03	0.08
46 Papaya (<i>Carica papaya</i>)	88.7	39	0.6	0.1	10.0	0.9	0.6	20	0.3	16	1750	56	0.3	0.04	0.03
47 Parsnip (<i>Pastinaca sativa</i>)	78.6	78	1.5	0.5	18.2	2.2	1.2	57	0.7	80	0	18	0.2	0.12	0.08
48 Pea, garden, immature (<i>Pisum sativum</i>)	74.3	98	6.7	0.4	17.7	2.2	0.9	22	1.9	122	680	26	2.7	0.16	0.34
49 Pea, garden, mature, dried (<i>P. sativum</i>)	11.6	339	23.8	1.4	60.2	5.4	3.0	57	4.7	388	370	2	3.1	0.28	0.77
50 Peach (<i>Prunus persica</i>)	86.9	46	0.5	0.1	12.0	0.6	0.5	8	0.6	22	880	8	0.9	0.05	0.02
51 Peanut, roasted (<i>Arachis hypogaea</i>)	2.6	559	26.9	44.2	23.6	2.4	2.7	74	1.9	393	0	(0)	16.2	0.13	0.30
52 Pear (<i>Pyrus communis</i>)	82.7	63	0.7	0.4	15.8	1.4	0.4	13	0.3	16	20	4	0.1	0.04	0.02
53 Pecan (<i>Carya illinoensis</i>)	3.0	696	9.4	73.0	13.0	2.2	1.6	74	2.4	324	50	2	0.9	0.11	0.72
54 Pepper, green (<i>Capsicum annuum</i>)	92.4	25	1.2	0.2	5.7	1.4	0.5	11	0.4	25	630	120	0.4	0.07	0.04
55 Pineapple (<i>Ananas sativus</i>)	85.3	52	0.4	0.2	13.7	0.4	0.4	16	0.3	11	130	24	0.2	0.02	0.08
56 Plantain (<i>Musa paradisiaca</i>)	66.4	119	1.1	0.4	31.2	0.4	0.9	7	0.7	30	10 ⁴	14	0.6	0.04	0.06
57 Plum (<i>Prunus spp</i>)	85.7	50	0.7	0.2	12.9	0.5	0.5	17	0.5	20	350	5	0.5	0.04	0.06
58 Potato (<i>Solanum tuberosum</i>)	77.8	83	2.0	0.1	19.1	0.4	1.0	11	0.7	56	20	17 ⁵	1.2	0.04	0.11
59 Prune (<i>Prunus spp</i>)	24.0	268	2.3	0.6	71.0	1.6	2.1	54	3.9	85	1890	3	1.7	0.16	0.10
60 Pumpkin (<i>Cucurbita pepo</i>)	90.5	31	1.2	0.2	7.3	1.3	0.8	21	0.8	44	(3400)	8	(0.6)	(0.08)	(0.05)
61 Radish (<i>Raphanus sativus</i>)	93.6	20	1.2	0.1	4.2	0.7	1.0	37	1.0	31	30	24	0.3	0.02	0.03
62 Raisin (<i>Vitis vinifera</i>)	24.0	268	2.3	0.5	71.2		2.0	78	3.3	129	50	Trace	0.5	0.08	0.15
63 Rice, brown (<i>Oryza sativa</i>)	12.0	360	7.5	1.7	77.7	0.6	1.1	39	2.0	303	(0)	(0)	4.6	0.05	0.32
64 Rice, white (<i>O. sativa</i>)	12.3	362	7.6	0.3	79.4	0.2	0.4	24	0.8	136	(0)	(0)	1.6	0.03	0.07
65 Rutabaga (<i>Brassica campestris</i>)	89.1	38	1.1	0.1	8.9	1.3	0.8	55	0.4	41	330	36	0.9	0.08	0.07
66 Rye (<i>Secale cereale</i>)	11.0	321	12.1	1.7	73.4	2.0	1.8	(38)	3.7	376	(0)	(0)	1.6	0.22	0.43
67 Soybean, mature, dried (<i>Glycine soja</i>)	7.5	331	34.9	18.1	34.8	5.0	4.7	227	8.0	586	110	Trace	2.3	0.31	1.07
68 Soybean, sprouts (<i>G. soja</i>)	86.3	46	6.2	1.4	5.3	0.8	0.8	48	1.0	67	180	13	0.8	0.20	0.23
69 Spinach (<i>Spinacia oleracea</i>)	92.7	20	2.3	0.3	3.2	0.6	1.5	81	3.0	55	9420	59	0.6	0.20	0.11
70 Squash, summer (<i>Cucurbita pepo</i>)	95.0	16	0.6	0.1	3.9	0.5	0.4	15	0.4	15	260	17	0.8	0.09	0.05
71 Squash, winter (<i>C. maxima</i>)	88.6	38	1.5	0.3	8.8	1.4	0.8	19	0.6	28	4950	8	0.5	0.12	0.05
72 Strawberry (<i>Fragaria spp</i>)	89.9	37	0.8	0.5	8.3	1.4	0.5	28	0.8	27	60	60	0.3	0.07	0.03
73 Sweetpotato (<i>Ipomoea batatas</i>)	68.5	123	1.8	0.7	27.9	1.0	1.1	30	0.7	49	7700	22	0.6	0.05	0.09
74 Tangerine (<i>Citrus reticulata</i>)	87.3	44	0.8	0.3	10.9	1.0	0.7	(33)	(0.4)	(23)	(420)	31	(0.2)	(0.03)	0.07
75 Tomato (<i>Lycopersicon esculentum</i>)	94.1	20	1.0	0.3	4.0	0.6	0.6	11	0.6	27	1100	23	0.5	0.04	0.06
76 Turnip (<i>Brassica rapa</i>)	90.9	32	1.1	0.2	7.1	1.1	0.7	40	0.5	34	Trace	28	0.5	0.07	0.05
77 Turnip greens (<i>B. rapa</i>)	89.5	30	2.9	0.4	5.4	1.2	1.8	259	2.4	50	9540	136	0.8	0.46	0.09
78 Walnut, English (<i>Juglans regia</i>)	3.3	654	15.0	64.4	15.6	2.1	1.7	83	2.1	380	30	3	1.2	0.13	0.48
79 Watermelon (<i>Citrullus vulgaris</i>)	92.1	28	0.5	0.2	6.9	0.6	0.3	7	0.2	12	590	6	0.2	0.05	0.05
80 Wheat (<i>Triticum aestivum</i>)	12.5	330	12.3	1.8	71.7	2.3	1.7	46	3.4	354	(0)	(0)	4.3	0.12	0.52

/1/ For yellow varieties, 150 I. U. /2/ Applicable to pared cucumber; for unpared, 1.2 mg iron and 260 I. U. vitamin A. /3/ Data also applicable to European grapes with the following modifications: food energy, 66 cal.; protein, 0.8 g; fat, 0.4 g; ash, 0.5 g. /4/ Applicable to white varieties; for yellow varieties, 1200 I. U. /5/ Year-round average. Recently harvested potatoes, 24 mg; after storage of 3 mo, 12 mg; after storage of 6 mo, 8 mg.

157. FEEDS OF ANIMAL AND PLANT ORIGIN: COMPOSITION

Table adapted from "Composition of Concentrate By-product Feeding Stuffs," Preliminary Report, Agricultural Board, National Research Council, 1956.

Feeding Stuff	Dry Matter %	Crude Protein %	Ether Extract %	Crude Fiber %	Ash %	N-Free Extract %	Calcium %	Cobalt mg/lb	Copper mg/lb	Iron %	Magnesium %	Manganese mg/lb	Phosphorus %	Sulfur %	Carotene mg/lb	Niacin mg/lb	Pantothenic Acid mg/lb	Riboflavin mg/lb	Thiamine mg/lb
Concentrates: Animal Origin																			
1 Blood, dried	91.8	80.1	1.6	0.6	5.4	4.1	1.10						0.68			11.4	2.2	1.3	0.1
2 Blood flour	90.8	82.2	1.0	0.6	4.8	2.2	0.45	0.04	3.7	0.28	0.04	2.9	0.37	0.60		13.0	2.4	1.9	0.2
3 Blood meal	90.5	79.9	1.6	0.8	5.6	2.6	0.28		4.5	0.38	0.22	2.4	0.22	0.38		14.3	0.5	0.7	
4 Bone meal, raw	93.2	26.2	4.6	1.4	57.8	3.2	22.14	0.05	8.5	0.04	0.35	3.9	10.35	0.12		1.9	1.0	0.6	0.1
5 Bone meal, steamed	95.2	12.1	3.2	1.7	71.8	6.4	28.98	0.03	7.4	0.08	0.61	13.8	13.59	0.22		1.9	1.1	0.4	0.2
6 Bone meal, sterilized	96.6	6.5	0.6	0.6	82.8	6.1	35.20				0.73		14.81						
7 Bone meal, unspecified	97.2	13.0	2.7	2.1	76.3	3.1	30.10	0.03	8.9	0.06	0.49	5.4	13.89	0.49		2.0	1.4	0.3	0.1
8 Buttermilk, dried	92.5	32.0	5.8	0.4	9.6	44.7	1.34				0.48	1.6	0.94	0.08		3.9	13.7	14.1	1.6
9 Cheese rind	74.5	31.3	27.4	0.1	4.0	11.7	0.86				0.02		0.49						
10 Crab meal	92.7	31.1	1.8	10.8	40.7	8.3	15.32		14.9	0.44	0.88	60.8	1.59	0.32			3.0	2.7	
11 Cracklings, dried	92.5	56.9	10.9	1.4	22.8	0.5	7.40					6.5	4.13					1.8	
12 Fish liver oil meal, cod	91.3	51.3	26.5	0.4	4.1	9.0	0.17					2.7	0.75			59.9	20.9	15.1	8.2
13 Fish meal, cod	94.0	58.9	1.6	0.7	29.9	2.9			1.3	0.017									
14 Fish meal, herring	92.3	70.6	7.5	0.4	10.8	3.0	2.94					4.5	2.20			40.4	5.2	4.1	
15 Fish meal, menhaden	92.2	61.3	7.7	0.7	19.6	2.9	5.49	0.09	3.8	0.06		11.7	2.81			25.4		2.2	0.3
16 Fish meal, salmon	93.0	58.0	9.6	0.3	16.7	8.4	5.44	0.03	5.4	0.02		3.6	3.26			11.3	3.1	2.6	0.4
17 Fish meal, sardine	93.2	65.5	4.3	0.8	15.7	6.9	4.90	0.08	9.2	0.03	0.10	10.1	2.77			28.2	4.2	2.7	0.2
18 Fish meal, unspecified	92.3	61.2	6.4	1.1	19.3	4.3	6.06	0.05	6.9	0.04	0.22	10.8	3.52	0.25		28.8	4.1	3.1	0.6
19 Fish meal, whitefish	91.6	63.2	4.4	0.7	21.7	1.6	7.87					6.5	3.61			31.7	4.0	4.1	0.8
20 Fish solubles product, dried	91.1	51.9	5.9	3.4	10.5	19.4	2.17						1.77			100.4	26.1	2.0	
21 Liver meal	92.6	66.5	15.1	1.3	6.0	3.7	0.50	0.06	40.5	0.06		4.0	1.25			92.9	20.5	21.0	0.1
22 Liver and glandular meal	93.4	65.1	16.0	1.6	5.8	4.9	0.66	0.09	44.1	0.05		3.3	1.14			73.4	48.2	18.5	1.2
23 Meat meal (meat scraps)	93.5	53.4	9.9	2.4	25.2	2.6	7.94	0.06	4.4	0.04	0.27	4.3	4.03	0.50		25.8	2.2	2.4	0.1
24 Meat meal, with bone	94.0	50.6	9.5	2.2	29.1	2.6	10.57	0.08	0.7	0.05	1.13	5.6	5.07			21.7	1.7	2.0	0.5
25 Milk albumin, dried	92.3	47.3	1.1	0.7	30.4	12.8	11.72						4.53			0.9	3.3	4.0	0.3
26 Milk, skimmed, dried	93.9	33.5	0.9	0.2	7.6	51.7	1.26	0.05	5.2	0.005	0.11	1.0	1.03	0.32		5.2	15.3	9.1	1.6
27 Milk, whole, dried	93.7	25.2	26.4	0.2	5.4	36.5	0.89		0.4	0.02		0.2	0.68			3.8	10.3	8.9	1.7
28 Shrimp meal	90.2	47.4	3.1	11.2	26.6	1.9	7.35			0.01	0.54	13.7	1.59		3.2	3.8		1.8	
29 Tankage, digester, unspecified	92.5	52.9	9.1	1.9	26.8	1.8	7.34		10.6	0.04		3.9	3.73			17.8	1.1	1.1	0.2
30 Tankage, digester, with bone	94.1	49.6	11.9	2.5	26.3	3.3	10.97						5.14						
31 Whale meat meal	92.1	78.9	6.8	0.5	4.0	1.9	0.25						0.56			47.6	1.2	3.8	0.6
32 Whale meal, with bone	92.4	54.0	9.8	1.4	25.8	1.4	8.29						4.16						
33 Whey, whole, dried	93.5	13.1	0.8	0.2	9.7	69.7	0.89	0.05	23.9	0.02		2.4	0.73	1.04		5.5	22.2	13.1	1.6
34 Whey, dried, cheese	94.7	13.1	0.5	0.3	8.3	72.5												8.1	
Concentrates: Plant Origin																			
35 Apple pomace, dried	91.1	5.4	4.7	16.6	1.9	62.5	0.13			0.03	0.06	3.3	0.12	0.02					
36 Barley feed	90.3	12.6	3.0	8.2	3.6	62.9	0.06			0.01	0.16	13.9	0.43	0.05	0.2	28.9	3.5	1.0	2.7
37 Barley meal	90.8	14.7	1.0	2.4	5.5	67.2	0.05	0.00	4.3	0.01		7.7	0.70			16.6	6.6	1.8	2.1
38 Beet pulp, dried	90.8	9.1	0.6	19.4	3.6	58.1	0.68	0.05	5.7	0.03	0.27	15.9	0.10	0.20	0.1	7.4	0.7	0.3	0.2
39 Brewers grains, dried	92.4	25.9	6.2	14.5	3.6	42.2	0.27	0.03	9.7	0.03	0.14	17.1	0.50	0.31		19.7	3.9	0.7	0.3
40 Brewers yeast, dried	93.4	44.6	1.1	2.7	6.4	38.6	0.13	0.08	15.0	0.01	0.23	2.6	1.43	0.38	0.0	203.4	49.9	15.9	41.7
41 Buckwheat feed	94.4	16.7	4.0	14.3	4.5	54.9			5.7	0.01		37.1	0.48						
42 Citrus pulp, dried	90.1	6.6	4.6	13.0	6.0	59.9	1.96	0.08	2.6	0.02	0.16	3.1	0.12		0.1	9.8	5.9	1.1	0.7
43 Citrus seed meal	87.8	35.3	6.6	9.8	6.5	29.6	1.20		3.0	0.03	0.60	3.4	0.69						
44 Coconut oil meal, unspecified	91.2	20.6	7.5	11.7	6.4	45.0	0.18		4.3	0.68	0.36	34.3	0.61	0.34		17.5	2.4	1.9	0.5
45 Corn bran, unspecified	89.3	7.5	4.4	9.7	2.1	65.6	0.03				0.26	7.3	0.19	0.07				0.7	2.0
46 Corn distillers grains, dried	92.3	27.1	9.3	11.9	2.6	41.4	0.09	0.04	20.3	0.02	0.06	8.6	0.37	0.39	1.4	19.2	2.6	1.4	0.8
47 Corn meal, unspecified	87.8	9.0	3.6	1.6	1.2	72.4	0.02		1.4	0.004	0.11	2.8	0.24	0.08					
48 Corn oil meal, unspecified	90.9	21.5	3.7	11.2	1.9	52.6	0.09		5.0	0.02	0.28	4.1	0.56		0.2	24.1	1.6	2.5	3.2
49 Corn screenings	89.5	14.1	3.9	10.1	3.6	57.8												2.1	
50 Cottonseed feed	90.8	39.2	6.1	11.6	6.1	27.8	0.15				0.39		0.64	0.12					
51 Cottonseed flour	94.2	56.4	6.9	2.3	6.3	22.3	0.22									35.0		4.2	4.3
52 Cottonseed hull bran	90.7	3.1	0.8	38.7	2.3	45.8	0.09	0.02	1.9	0.005		7.6	0.10			3.5		0.2	0.1
53 Cottonseed oil meal, unspecified	92.5	40.6	6.1	10.1	6.1	29.6	0.20	0.07	8.9	0.03	0.56	9.3	1.09	0.41	0.1	17.0	5.7	2.9	3.7
54 Distillers grains, dried	91.6	29.1	8.9	11.5	3.1	39.0	0.20	0.04	21.5	0.03	0.12	15.7	0.55	0.45	3.5	21.0	5.2	1.7	1.1
55 Flaxseed screenings	91.4	15.8	9.4	12.4	6.7	47.1	0.37						0.43						

56	Grapefruit pulp, dried	87.6	7.6	4.8	13.4	4.9	56.9	1.30				0.38		0.16						
57	Linseed feed	90.5	33.8	4.8	9.5	6.0	36.4	0.43						0.65						
58	Linseed oil meal, unspecified	90.0	35.2	5.7	7.8	5.5	36.7	0.35	0.14	9.6	0.02	0.48	18.0	0.85	0.35	0.1	20.2	3.3	1.4	3.0
59	Mustard seed oil meal	94.4	31.1	6.2	11.1	6.4	39.6													
60	Oat feed	92.1	4.5	1.8	30.4	5.1	50.3	0.08						0.22	0.15					
61	Oatmeal	90.7	16.1	6.3	3.0	2.2	63.1	0.07	0.02	1.6	0.01		18.7	0.45			5.8	5.6	0.8	3.2
62	Orange pulp, dried	89.3	7.0	1.8	9.6	4.4	66.5	0.63						0.10						
63	Peanut oil meal, unspecified	93.5	42.6	8.3	11.0	5.2	26.4	0.16				0.03	0.22	0.56	0.10	0.1	79.0	24.2	2.1	3.1
64	Pineapple pulp, dried	89.1	4.2	1.5	17.0	3.1	63.3	0.21				0.03		0.11						
65	Potato meal, dehydrated	90.3	5.9	0.5	1.4	11.9	70.6													
66	Potato pomace, dried	88.6	7.7	0.4	6.1	4.2	70.2													
67	Rice bran, unspecified	90.6	13.5	15.1	10.9	10.9	40.2	0.06		5.9	0.12	0.95	189.9	1.82	0.18		137.8	10.7	2.8	5.4
68	Rice meal	91.5	8.3	1.0	4.6	1.1	76.5						75.3					1.2		10.2
69	Rice screenings	88.2	8.0	0.5	0.4	0.6	78.7	0.03				0.05		0.26			10.6			0.4
70	Rye bran	90.0	16.5	2.0	3.3	2.8	65.4													
71	Rye distillers grains, dried	93.0	22.4	6.4	13.8	2.6	47.8	0.13				0.17	8.4	0.41	0.44		7.7	2.4	1.5	0.6
72	Rye feed	89.7	17.2	3.4	4.6	3.8	60.7	0.07				0.23		0.59	0.04					
73	Rye middlings	89.8	17.1	3.1	5.8	3.4	60.4	0.06					20.0	0.63						
74	Safflower oil meal, unspecified	91.8	21.4	3.9	32.3	4.7	29.5	0.37					9.3	0.92						
75	Sesame oil meal, unspecified	93.3	41.3	8.4	6.1	11.8	25.7	2.07					48.8	1.38		0.18		2.9	1.7	1.3
76	Sorghum bagasse	92.5	3.5	1.3	28.5	3.0	56.2													
77	Sorghum gluten meal, unspecified	90.1	41.7	4.3	3.0	1.3	39.8	0.04				0.16	7.3	0.31			15.5	4.6	0.7	
78	Sorghum meal, milo sorghum	88.1	11.2	2.7	2.7	2.2	69.3	0.04				0.12	10.0	0.27						
79	Soybean oil meal, unspecified	90.1	44.7	3.2	5.5	5.9	30.8	0.26	0.03	8.2	0.02	0.25	14.0	0.61	0.19		15.1	7.0	1.6	1.6
80	Sunflower oil meal, unspecified	91.6	43.9	2.3	13.6	6.6	25.2	0.39				0.69	2.3	0.99		4.0	132.4	18.6	1.5	15.7
81	Tomato pomace, dried	92.0	21.7	13.0	29.0	4.2	24.1	0.28					21.5	0.57						
82	Wheat bran, unspecified	89.1	16.0	4.1	9.9	6.1	53.0	0.14	0.04	5.6	0.02	0.55	52.6	1.17	0.22	1.2	95.1	13.2	1.4	3.6
83	Wheat flour	89.1	15.8	2.9	2.6	2.1	65.7	0.03		2.1	0.002		20.4	0.28			19.0		0.4	2.7
84	Wheat germ oil meal	89.7	27.3	9.1	2.6	4.8	45.9	0.07	0.02	4.2	0.01		74.6	1.06		3.0	23.3	5.6	2.3	11.5
85	Wheat mill feed (mixed feed)	89.9	15.3	4.0	8.2	5.2	57.2	0.09	0.10	8.5	0.01	0.51	46.7	1.02			50.9	6.0	1.1	6.9
86	Wheat screenings	89.3	15.0	3.0	6.5	3.2	61.6	0.08					13.0	0.36						2.9
87	Wheat standard middlings, unspecified	89.7	17.2	4.6	7.6	4.4	55.9	0.15	0.04	10.0	0.01	0.37	53.8	0.91	0.05	1.4	44.8	9.0	0.9	5.8
88	Wheat distillers grains, dried	93.0	33.8	5.8	12.4	2.4	38.6	0.10						0.50		0.5	25.4	3.7	1.7	0.9
89	Yeast distillers molasses, dried	94.5	24.0	0.6	7.4	14.0	48.5										116.0	16.4	12.3	34.8
Dry Roughages																				
90	Alfalfa hay	90.5	14.8	2.0	28.9	8.2	36.6	1.47			3.67	0.03		20.48	0.24		11.40	17.38	8.08	1.32
91	Bluegrass hay, Kentucky	84.3	9.5	2.3	25.2	7.2	40.1	0.46			4.09	0.03		34.74	0.32			4.49	6.17	
92	Brome hay, smooth	86.8	5.7	4.4	28.5	8.2	40.0													
93	Brome grass hay	88.1	9.9	2.1	28.4	8.2	39.5	0.20						14.98	0.28		16.98			
94	Clover hay, alsike	88.9	12.1	2.1	27.0	7.8	39.9	1.15			2.41	0.04		47.13	0.23		47.22			
95	Clover hay, crimson	89.5	14.2	2.2	27.4	8.7	37.0	1.23						99.79	0.24					
96	Clover hay, Ladino	88.0	19.4	3.2	20.7	9.8	34.9	1.32				0.10		72.50	0.29					
97	Clover hay, red	88.1	11.8	2.6	27.2	6.4	40.1	1.35			4.00	0.03		48.35	0.19		4.04	16.89	4.49	0.86
98	Corn cobs	90.4	2.3	0.4	32.1	1.6	54.0								0.02					
99	Corn fodder	82.6	6.8	2.1	21.8	5.2	46.7	0.21							0.14		1.77			
100	Cowpea hay	90.4	18.6	2.6	23.3	11.3	34.6	1.37				0.08			0.29					
101	Grass hay	89.9	6.7	1.8	28.9	7.6	44.9	0.48				0.06			0.21					
102	Lespedeza hay, annual	89.2	12.7	2.4	26.7	5.2	42.2	0.98				0.03		59.15	0.18		22.43			
103	Oat hay	88.1	8.2	2.7	28.1	6.9	42.2	0.21				0.05		36.55	0.19					
104	Orchard grass hay	85.8	6.9	2.6	30.9	6.8	38.6	0.19							0.17					
105	Prairie hay	90.7	5.7	2.3	30.4	7.4	44.9	0.36							0.18		9.31			
106	Redtop hay	90.7	8.5	3.4	26.8	4.3	47.7	0.38		1.59	0.01		9.35	0.23						
107	Sorghum fodder, sweet	88.8	6.2	2.4	25.0	7.1	48.1	0.34					52.62	0.12		1.09				
108	Soybean hay	88.0	14.4	3.3	27.5	7.0	35.8	1.35						0.25		13.57				
109	Sudan grass hay	89.3	8.8	1.6	27.9	8.1	42.9	0.36				0.01		37.05	0.26		37.23			
110	Sweet clover hay	92.2	15.8	1.6	24.7	10.8	39.3	1.25			4.09	0.01		48.53	0.23					
111	Timothy hay	89.0	6.5	2.4	30.2	4.9	45.0	0.23						0.20		5.32	15.48		4.09	0.59
112	Vetch hay, common	85.2	18.7	1.8	22.2	7.8	34.7	1.13			4.00	0.03		21.52	0.32					
113	Wheat hay	90.4	6.1	1.8	26.1	6.4	50.0	0.14						0.18						
Silages																				
114	Alfalfa	25.3	4.6	0.9	8.2	2.3	9.3	0.35			1.09	0.007		5.99	0.08		21.11			
115	Corn	23.8	1.8	0.7	6.4	1.5	13.4	0.10			0.59	0.003		8.80	0.06		6.40			
116	Grass	24.3	3.1	0.8	7.3	2.6	10.5										24.33			

158. FOODS OF ANIMAL ORIGIN: COMPOSITION

Values are per 100 grams of edible portion of fresh, uncooked food, unless otherwise specified. Values based on inadequate evidence are enclosed in parentheses.

Food	Water g	Food Energy Cal	Pro- tein g	Fat g	Carbohydrate Total g	Fiber g	Ash g	Ca mg	Fe mg	P mg	Vitamin A I. U.	Ascor- bic acid mg	Niacin mg	Ribo- flavin mg	Thiamine mg
Dairy Products															
1 Butter	15.5	716	0.6	81	0.4	0	2.5	20	0	16	3300 ¹	0	0.1	0.01	Trace
2 Buttermilk	90.5	36	3.5	0.1	5.1	0	0.8	(118)	0.1	93	Trace	1	0.1	0.18	0.04
3 Cheese: Cheddar	37	398	25.0	32.2	2.1	0	3.7	725	1.0	495	1400	(0)	Trace	0.42	0.02
4 Cottage	76.5	95	19.5	0.5	2.0	0	1.5	96	0.3	189	(20)	(0)	(0.1)	0.31	0.02
5 Cream	51	371	9.0	37.0	2.0	0	1.0	68	0.2	97	(1450)	(0)	0.1	0.22	(0.01)
6 Swiss	39	370	27.5	28.0	1.7	0	3.8	925	0.9	563	1450	(0)	(0.1)	0.40	0.01
7 Cream, light	72.5	204	2.9	20.0	4.0	0	0.6	97	0.1	77	830	1	0.1	0.14	0.03
8 Milk, cow: whole	87	68	3.5	3.9	4.9	0	0.7	118	0.1	93	(160)	1	0.1	0.17	0.04
9 Skimmed	90.5	36	3.5	0.1	5.1	0	0.8	123	0.1	97	Trace	1	0.1	0.18	0.04
10 Milk, goat	87.4	67	3.3	4.0	4.6	0	0.7	129	0.1	106	(160)	1	0.3	0.11	0.04
Meats															
11 Beef: chuck	65	224	18.6	16	0	0	0.9	11	2.8	167	(0)	0	4.5	0.17	0.08
12 Flank	61	247	19.9	18	0	0	0.9	12	3.0	186	(0)	0	4.8	0.18	0.09
13 Hamburger	55	321	16.0	28	0	0	0.8	9	2.4	128	(0)	0	3.8	0.14	0.07
14 Heart	77.6	108	16.9	3.7	0.7	0	1.1	9	4.6	203	30	6	7.8	0.89	0.58
15 Kidney	74.9	141	15.0	8.1	0.9	0	1.1	9	7.9	221	1150	13	6.4	2.55	0.37
16 Liver	69.7	136	19.7	3.2	6.0	0	1.4	7	6.6	358	43,900	31	13.7	3.33	0.26
17 Porterhouse	58	296	16.4	25	0	0	0.8	10	2.5	134	(0)	0	3.9	0.15	0.07
18 Rib roast	59	282	17.4	23	0	0	0.8	10	2.6	149	(0)	0	4.2	0.15	0.07
19 Round	69	182	19.5	11	0	0	1.0	11	2.9	180	(0)	0	4.7	0.17	0.08
20 Rump	55	322	16.2	28	0	0	0.8	9	2.4	131	(0)	0	3.9	0.14	0.07
21 Sirloin	62	254	17.3	20	0	0	0.9	10	2.6	147	(0)	0	4.2	0.15	0.07
22 Tongue	68	207	16.4	15.0	0.4	(0)	0.9	9	2.8	187	(0)	(0)	5.0	0.29	0.12
23 Brains	78.9	125	10.4	8.6	0.8	0	1.4	16	3.6	330	0	18	4.4	0.26	0.23
24 Lamb: leg roast	63.7	235	18.0	17.5	0	0	0.9	10	2.7	213	(0)	0	5.2	0.22	0.16
25 Liver	70.8	136	21.0	3.9	2.9	0	1.4	8	12.6	364	50,500	33	16.9	3.28	0.40
26 Kidney	77.8	105	16.6	3.3	1.0	0	1.3	13	9.2	237	(1150)	13	7.4	2.42	0.51
27 Shoulder roast	58.3	295	15.6	25.3	0	0	0.8	9	2.3	155	(0)	0	4.5	0.19	0.14
28 Pork: bacon	20	630	9.1	65	1.1	0	4.3	13	0.8	108	(0)	0	1.9	0.12	0.38
29 Ham, fresh	53	344	15.2	31.0	0	0	0.8	9	2.3	168	(0)	0	4.0	0.18	0.74
30 Ham, smoked	42	389	16.9	35.0	(0.3)	0	5.4	10	2.5	136	(0)	0	4.0	0.19	0.70
31 Heart	76.8	117	16.9	4.8	0.4	0	1.1	35	2.7	132	30	6	6.0	1.24	0.43
32 Kidney	77.1	114	16.3	4.6	0.8	0	1.2	11	8.0	246	130	13	9.8	1.74	0.58
33 Liver	72.3	134	19.7	4.8	1.7	0	1.5	10	18.0	362	14,200	23	16.7	2.98	0.40
34 Loin or chops	58	296	16.4	25	0	0	0.9	10	2.5	186	(0)	0	4.3	0.19	0.80
35 Salt pork, fat	8	783	3.9	85	0	(0)	3.5	Trace	0.6	Trace	(0)	0	(0.9)	(0.04)	(0.18)
36 Sausage	41.9	450	10.8	44.8	0	0	2.1	6	1.6	100	(0)	0	2.3	0.17	0.43
37 Spare rib, medium	53	351	14.6	32	0	0	0.8	8	2.2	158	(0)	0	3.8	0.17	0.71
38 Rabbit, domesticated	54	122	16	6	0	0	0.8	15	1.0	271			9.9	0.04	0.06
39 Seal, canned	66	183	19.1	10.6	1.4				11.4				4.9	0.09	0.04
40 Veal: cutlet	70	164	19.5	9.0	0	0	1.0	11	2.9	200	(0)	0	6.5	0.26	0.14
41 Leg roast	68	186	19.1	12.2	0	0	1.0	11	2.9	206	0	0	6.3	0.27	0.17
42 Liver	71	141	19.0	4.9	4	0	1.3	6	10.6	343	22,500	36	16.1	3.12	0.21
43 Shoulder roast	70	173	19.4	10.0	0	0	1.0	11	2.9	199	(0)	0	6.5	0.26	0.14
44 Stew meat	64	231	18.3	17.0	0	0	0.9	11	2.7	182	(0)	0	6.1	0.24	0.13
45 Venison	73	140	20	6.0	0	0	1.0	12	3.0	216					0.14
Poultry and Eggs															
46 Chicken: broiler	71.2	151	20.2	7.2	0	0	1.1	14	1.5	200	(0)	(0)	10.2	0.16	0.08
47 Heart	69.6	157	20.5	7.0	1.6	0	1.3	23	1.7	142	30	6	5.2	0.91	0.12
48 Liver	69.6	141	22.1	4.0	2.6	0	1.7	16	7.4	240	32,200	20	11.8	2.46	0.20
49 Roaster	66.0	200	20.2	12.6	0	0	1.0	14	1.5	200	(0)	(0)	8.0	0.16	0.08
50 Egg, whole	74.0	162	12.8	11.5	0.7	0	1.0	54	2.7	210	1140	0	0.1	0.29	0.10
51 Egg white	87.8	50	10.8	0	0.8	0	0.6	6	0.2	17	(0)	0	0.1	0.26	0
52 Egg yolk	49.4	361	16.3	31.9	0.7	0	1.7	147	7.2	586	3210	0	Trace	0.35	0.27
53 Duck	54	326	16.1	29	0	0	1.3	9	2.4	172	0	0	6.0	0.23	0.16
54 Goose	50	354	16.4	32	0	0	0.9	9	2.4	176		9	5.6		0.15
55 Squab	58	279	18.6	22.1	0	0	1.5	12	3.0	217					
56 Turkey	58.3	268	20.1	20.2	0	0	1.0	23	3.8	320	Trace	(0)	8.0	0.14	0.09
Fish and Shellfish															
57 Bluefish	74.6	124	20.5	4.0	0	0	1.2	23	0.6	243			1.9	(0.09)	(0.12)
58 Clam	80.3	81	12.8	1.4	3.4		2.1	(96)	(7.0)	(139)	110		(1.6)	0.18	0.10
59 Cod	82.6	74	16.5	0.4	0	0	1.2	10	0.4	194	0	2	2.2	0.09	0.06
60 Crab	80.0	86	16.1	1.6	0.6		1.7	(39)	(0.8)	(160)			2.7	0.06	0.14
61 Eel	71.6	162	18.6	9.1	0	0	1.0	18	0.7	202	1800		1.4	0.37	0.28
62 Flounder	82.7	68	14.9	0.5	0	0	1.3	61	0.8	195			1.7	0.05	0.06
63 Haddock	80.7	79	18.2	0.1	0	0	1.4	23	0.7	197			2.4	0.08	0.05
64 Halibut	75.4	126	18.6	5.2	0	0	1.0	13	0.7	211	440		9.2	0.06	0.07
65 Herring, Atlantic	67.2	191	18.3	12.5	0	0	2.7		1.1	256	110		3.4	0.15	0.02
66 Herring, Pacific	79.6	94	16.6	2.6	0	0	1.3				100		(2.2)	0.22	0.02
67 Lobster	79.2	88	16.2	1.9	0.5	0	2.2	61	0.6	184			(1.9)	0.06	(0.13)
68 Mackerel	68.1	188	18.7	12.0	0	0	1.2	5	1.0	239	(450)		8.4	0.35	0.15
69 Oyster	80.5	84	9.8	2.1	5.6		2.0	94	5.6	143	320		1.2	0.20	0.15
70 Perch, yellow	80	88	18.7	0.9	0	0	1.2	20	1.0	215			1.7	0.07	0.09
71 Salmon	63.4	223	17.4	16.5	0	0	1.0		(0.9)	(289)	310		7.2	0.23	0.10
72 Sardine, canned	57.4	214	25.7	11.0	1.2		(4.7)	386	2.7	586	220	(0)	4.8	0.17	0.02
73 Scallop	80.3	78	14.8	0.1	3.4	0	1.4	26	1.8	208	0		1.4	0.10	(0.04)
74 Shad	70.2	168	18.7	9.8	0	0	1.4		0.5	260			(8.4)	0.24	(0.15)
75 Shrimp, canned	66.2	127	26.8	1.4	0		5.8	115	3.1	263	60	(0)	2.2	0.03	0.01
76 Swordfish	75.8	118	19.2	4.0	0	0	1.3	19	0.9	195	1580		9.1	0.05	0.05
77 Tuna, canned	60.0	198	29.0	8.2	0	0	2.7	(8)	1.4	(351)	80	(0)	12.8	0.12	0.05
78 Whitefish	70	156	22.9	6.5	0	0	1.6	25	1.3	263			(4.2)	(0.09)	(0.09)

/1/ Year-round average.

159. FERTILIZERS: CHEMICAL ELEMENT COMPOSITION AND NEUTRALIZING ACTION

Values are g per 100 g of fertilizers, and where composition of fertilizer material is variable, they are averages of several determinations for total element present (cf Fn 2 for exceptions in case of phosphorus and potassium).

Fertilizer Materials		Ca	Mg	N	P ²	K ²	S	Action
Inorganic Fertilizers								
N Materials								
1	Ammonia, anhydrous			82				Acidic
2	Ammonia solution ³			21-25				Acidic
3	Ammonium chloride			24				Acidic
4	Ammonium nitrate			32-34				Acidic
5	Ammonium sulfate			20			24	Acidic
6	Calcium ammonium nitrate (A.N.L.)	7.1-14	0-4.5	20				Neut.
7	Calcium cyanamide ⁴	39		21			0.4	Basic
8	Calcium nitrate	20		16				Basic
9	Calcium nitrate-urea ⁵	9.3		34				Acidic
10	Sodium nitrate			16				Basic
11	Urea (Uramon)			42-46				Acidic
12	Urea-ammonia liquor			46				Acidic
P Materials								
13	Basic slag, Bessemer	34	2.4		7		0.2	Basic
14	Basic slag, open-hearth	32	3		2.2-6.5		0.2	Basic
15	Phosphate rock, defluorinated	20-30			7.9-10			Basic
16	Phosphoric acid, liquid				24		1.4 ⁶	Acidic
17	Superphosphate, double	12-14	0.3		19-21		1	Neut.
18	Superphosphate, ordinary	18-21	0.3		6.1-8.7		11-12	Neut.
K Materials								
19	Alunite, calcined	2.9	0.3			4.6	2	
20	Kainite	0.4-3.6	0-9			10-18	0.4-10	Neut.
21	Manure salts	0-0.7	0-3.6			21-33	0-5.2	Neut.
22	Potassium carbonate					54	0.2	Basic
23	Potassium chloride	0-2.1	0-1.8			40-51	0-2.8	Neut.
24	Potassium magnesium sulfate	0-4.6	3.6-12			17-25	13-22	Neut.
25	Potassium sulfate	0-1.8	0-1.2			40-43	16-19	Neut.
N-P, N-K Materials								
26	Ammoniated superphosphate, double	12-14	0.3	4-6	18-21		1	Acidic
27	Ammoniated superphosphate, ordinary	17-21	0.3	2-5	5.9-8.5		11-12	Acidic
28	Monoammonium phosphate ^{7,8}	1.1	0.3	11	21		2.4	Acidic
29	Monoammonium phosphate-ammonium sulfate ^{7,9}	0.4		16	8.7		15	Acidic
30	Urea-superphosphate			7	6.5			Acidic
31	Potassium ammonium chloride ¹⁰			13		18		Acidic
32	Potassium nitrate	0.4	0.3	13		37		Basic
33	Sodium potassium nitrate			15		12		Basic
N-P-K, P-K Materials								
34	Ammonium potassium phosphate			5.5	24	15		Acidic
35	Monopotassium phosphate				23	29		Neut.
36	Potassium metaphosphate	0.4			24	32		Neut.
Organic Fertilizers								
Animal By-products								
37	Blood, dried	0.4		13	0.9	0.8		Acidic
38	Bone meal, raw	22	0.6	4	9.8		0.2	Basic
39	Bone meal, steamed	24	0.3	2.5	11		0.2	Basic
40	Fish scrap or meal, dried	6.1	0.3	9.5	3.1		0.2	Acidic
41	Hoof and horn meal	1.8		14	0.4		0.8	Acidic
42	Tankage, animal	11	0.3	7	4.4	0.4	0.4	Basic
43	Tankage, process	0.4		9	0.2		0.4	Acidic
44	Whale guano or tankage	6.4	0.3	9.5	2.8			Acidic
45	Wool waste	0.4		3.5	0.2	1.7		
Animal Excreta								
46	Guano, bat	5.4	0.3	8.5	2.2	1.2	0.8	Acidic
47	Guano, Peruvian	7.9	0.6	13	5.2	2.1	1.4	Acidic
48	Manure, cattle	2.9	0.6	2	0.7	1.7	0.2	Basic
49	Manure, horse	1.1	0.6	2	0.7	1.2	0.2	Basic
50	Manure, poultry	2.9	0.6	5	1.3	1.2	0.8	Acidic
51	Manure, sheep	3.6	1.2	2	0.7	2.5	0.6	Basic
52	Sewage sludge, activated	1.8	0.9	6	1.3	0.4	0.4	Acidic
53	Sewage sludge, dried	1.8	0.3	2	0.9		0.2	Acidic
Plant Residues								
54	Castor pomace	0.4	0.3	5.5	0.7	1.2		Acidic
55	Cocoa shell meal	1.1	0.3	2.5	0.4	1.7		Basic
56	Cottonseed hull, ash	6.8	3		2.4	22	1	Basic
57	Cottonseed meal	0.4	0.3	7	1.3	1.7	0.2	Acidic
58	Garbage tankage	3.2	0.3	2.5	1.3	0.8	0.4	Basic
59	Kelp, Pacific	1.1	0.6	2.5	0.7	12	1	
60	Linseed meal	0.4	0.6	5.5	0.9	1.2	0.4	
61	Peat, moisture-free	0.7	0.3	2			0.2	Acidic ¹¹
62	Seaweed	2.1	0.6	1.5	0.2	1.7	1.4	
63	Soybean meal	0.4	0.3	7	0.7	2.1	0.2	Acidic
64	Tobacco, ash	16	3.6		1.3	19		Basic
65	Tobacco stems	3.6	0.3	2	0.2	5	0.4	Basic
66	Wood ash, commercial	23	2.1		0.9	4.2	0.4	Basic

/1/ For conversion of values for elements to those for commonly used oxides of the elements, the following factors are employed: Ca x 1.399 = CaO, Mg x 1.658 = MgO, P x 2.291 = P₂O₅, K x 1.205 = K₂O; S x 2.497 = SO₃. /2/ Values for phosphorus (from inorganic fertilizers) are applicable to available phosphorus, i.e., amount of phosphorus soluble in water or in solutions of salts or acids. Values for potassium (from inorganic fertilizers) are applicable to water-soluble potassium. /3/ Includes ammonium hydroxide, aqua ammonia, ammonia liquor, "B" liquor. /4/ Also known as Cyanamid, Nitrolime. /5/ Also known as Calurea. /6/ Sulfate content arises from H₂SO₄ process used in production of P₂O₅. /7/ Data applicable to material prepared with P₂O₅ manufactured by the H₂SO₄ process. Material made with electric furnace P₂O₅ has higher purity. /8/ Also known as Ammo-Phos A. /9/ Also known as Ammo-Phos B. /10/ Also known as Potazote. /11/ Some peats may be basic.

160. NUTRIENTS: STABILITY AND LABILITY

Nutrients are especially sensitive to the reaction (pH) of the solvent, and to exposure to air, light and heat. Unless otherwise specified, reference is made to the properties of the nutrient in aqueous solution. Where no footnote is given, the stability of the nutrient is estimated on the basis of its chemical composition, or other well-known properties.

S = stable, i.e., nutrient exhibits no appreciable breakdown under the conditions specified. L = labile, i.e., nutrient exhibits appreciable decomposition under the conditions specified. +++ = appreciable loss; + = slight loss.

Nutrient	pH7	<pH7	>pH7	Oxygen	Light	Heat	% Loss in Cooking ¹	Nutrient	pH7	<pH7	>pH7	Oxygen	Light	Heat	% Loss in Cooking ¹
Vitamins								Vitamins (concluded)							
1 A	S ²			L ²	L	S ²	10-30	15 Riboflavin	S ²⁰	S ²¹	L	S ²¹	L ²²	S ²⁰	0-48
2 Ascorbic acid	L ³	S ³	L ³	L ³	L ³	L ³	20-80	16 Thiamine	L ²³	S ²⁴	L ²⁵	L ²⁶	S ²⁴	L ^{23,25}	25-45
3 Biotin	S	S	S	S	S	S	0-72	17 Unsaturated fatty acids	S	S	L	L ²⁷	L ²⁷	S	<10
4 Choline	S	S	S	L	S	S		Amino acids²⁸							
5 Cobalamin	S ⁴	S ⁴	S ⁴	L	L	S ⁴		18 Isoleucine	S	S	S	S	S	S	+
6 D ₂ ⁵	S			L ⁶	L ⁶	L ⁶	+++	19 Leucine	S	S	S	S	S	S	+
7 E	S	S	S	L ⁷	L ⁷	L ⁷	50 ⁹	20 Lysine	S	S	S	S	S	S	+
8 Folic acid group	L	L ¹⁰	S ^{10,11}	L ¹¹	L ¹²	S ¹⁰	0-97	21 Methionine	S	S	S	S	S	S	+
9 Inositol	S	S ¹³	S	S	S	S ¹³	0-95	22 Phenylalanine	S	S	S	S	S	L ²⁹	S
10 K	S	S	L ¹⁴	S	L	S		23 Threonine	S	S	L	S	S	S	+
11 Niacin ¹⁵	S	S	S	S	S	S	0-72	24 Tryptophan	S	L	S	S	L ²⁹	S	+
12 Pantothenic acid	S	L	L	S	S	L	0-44	25 Valine	S	S	S	S	S	S	+
13 p-Aminobenzoic acid	S	S ¹⁶	S ¹⁷	L	S	S		26 Inorganic salts	S	S	S	L ³⁰	S	S	+
14 Pyridoxine group	S ¹⁸	S ¹⁸	S ¹⁸	S ¹⁹	L	S ¹⁸									

/1/ Nutrient loss expressed as percentage of quantity of nutrient present before cooking. /2/ Loses biological activity if heated in presence of oxygen for 5.5 hours. /3/ Decomposes in light; decomposition accelerated by oxygen, metal ions. /4/ Stable in boiling water at pH 7 for 2 hours. /5/ Stable in dry propylene glycol more than three years when stored in amber bottles. /6/ Activity lost in mixed feeds, also under prolonged irradiation in presence of oxygen. /7/ In absence of oxygen, stable to heat up to 200°C. /8/ Tocopherols stable to visible light, but readily destroyed by UV. /9/ Deep fat frying and baking result in appreciable destruction. /10/ No destruction at pH 6.8 and 100°C for 30 minutes. /11/ Aeration at pH 10 causes partial inactivation. /12/ Rapidly inactivated by light. /13/ Stable to refluxing with 10% HCl for 6 hours, to alkali and to a variety of chemical agents. /14/ Sensitive to alkali. /15/ Nicotinamide is partially hydrolyzed by alkali and acid, but the product, nicotinic acid, having the same vitamin activity as nicotinamide retains its biological activity. /16/ Only 15% destruction on autoclaving solutions in 6N H₂SO₄ for 60 minutes. /17/ Long treatment with alkali results in destruction. /18/ Pyridoxine not destroyed by heating with 5N acid or alkali at 100°C, or autoclaving in acid or alkali; pyridoxal and pyridoxamine stable in hot acid, but pyridoxal partially decomposed by hot alkali. /19/ Oxidized only by such strong agents as hot HNO₃, H₂O₂. /20/ Stable in neutral or acid solutions. /21/ 1/2% decomposed per month at pH 5.0 at 27°C. /22/ 50% of the riboflavin of milk destroyed when exposed to sunlight for 2 hours. /23/ 96.4% destroyed at 100°C at pH 7 in 3 hours. /24/ No destruction in 1% HCl in 7 hours at 100°C. /25/ 100% destroyed in 15 minutes at pH 9 at 100°C. /26/ Unstable in presence of air. /27/ Sensitive to light and air oxidation. /28/ Most amino acids undergo racemization in alkaline solutions, but they are otherwise stable. /29/ Modified by UV. /30/ Oxidation of some inorganic salts of lower valence to higher valence states (e.g., ferrous to ferric iron) when exposed to atmospheric oxygens.

161. NUTRIENT LOSSES IN COOKING

Values are rough approximations of the percentage of nutrients lost in various types of cooking. I = baking; II = boiling; III = braising; IV = broiling; V = double boiler; VI = pressure saucepan; VII = roasting; VIII = steaming; IX = stewing; X = discarding water or drippings; XI = retaining water or drippings; XII = mashed; XIII = frying.

	Food Type	Minerals				Vitamins ¹						Food Type	Minerals				Vitamins ¹				
		Cooking Method	Ca	Fe	P	A	C	Niacin	Ribo-flavin	Thia-mine			Cooking Method	Ca	Fe	P	A	C	Niacin	Ribo-flavin	Thia-mine
1	Cabbage ^{2,3}	II;XI					10	25	1		22	Potatoes ² (concluded)	II;XI						15		
2		II;X					40	25	15		23		II;X	15	10	0		20	20		20
3		VI					30				24		XII					50			
4		VIII					50	20	15		25		VI					30	0	5	5
5	Cereals ⁴	V;15 min						0	0	0	26	Roots and bulbs ^{2, 9}	VIII					15			
6		V;30 min						0	0	2	27		II;XI				5	10	15	15	
7		V;120 min						0	0	8	28		II;X	1	5	0	65	35			
8	Corn ²	II					35	15	10	20	29	VI	25	5	15		5	50	40	25	
9	Flowers and shoots ^{2, 5}	II;XI				0	10	15		1	30	Squash ²	VIII				55			50	
10		II;X	20	5	15	0	30	25	35	40	31										
11		VI					30				32										
12	Leafy ^{2, 6}	VIII				0	25	15	15	15	33	Meats ¹⁰	III;XI					10	5	40	
13		II;XI					25	20	10	5	34		III;X					35	25	55	
14		II;X	20	5	15		50	25	30	30	35		IV;XI					5	10	25	
15		VI					50				36		IV;X					20	20	30	
16	Legumes, fresh ^{2, 7}	VIII				60	10	15	15	37	Fish ¹⁰	VII;XI					5	10	30		
17		II;XI					5	5	0	10		38	VII;X					20	15	40	
18		II;X	0	1	5	15	40	20	20	20		39	IX;XI					0	0	50	
19	Potatoes ²	VIII				10	15	0	5	5	40	IX;X					50	30	75		
20		I					25				41	XIII					5	10			
21		II ⁸				0						VIII					5	0			

/1/ Loss of water soluble vitamins increases in proportion to amount of cooking water used. /2/ Cooked immediately, without standing after preparation. /3/ Also Brussels sprouts. /4/ Rolled oats. /5/ Asparagus, broccoli, cauliflower. /6/ Kale, spinach, Swiss chard. /7/ Beans, peas. /8/ Boiled in jackets. /9/ Beets, carrots, onions, parsnips, turnips. /10/ Unspecified.

162. NUTRITIVE VALUE PER POUND: SELECTED FOODS AND GROUPS OF FOODS¹

Item	Food Energy Cal	Protein g	Fat g	Carbo-hydrate g	Calcium mg	Iron mg	Vitamin A I.U.	Thiamine mg	Ribo-flavin mg	Niacin mg	Ascorbic Acid mg
1 Meat, poultry, fish	920	63	70.9	0.3	60	9.1	1600	0.99	0.83	18.9	3
2 Meat	1050	64	84.0	0.4	40	10.8	1900	1.30	0.97	17.7	5
3 Poultry, fish	600	59	38.3	0.1	100	4.9	800	0.24	0.48	21.8	0
4 Eggs	655	52	46.5	2.8	220	10.9	4600	0.39	1.17	0.3	0
5 Leafy, green, and yellow vegetables	130	8	1.0	26.5	180	3.9	9200	0.31	0.34	2.4	101
6 Leafy vegetables	60	6	0.9	11.5	220	3.6	8900	0.17	0.38	1.6	91
7 Other green and yellow vegetables	150	9	1.0	30.9	170	4.0	9300	0.34	0.33	2.7	104
8 Citrus fruit, tomatoes	150	4	1.1	35.4	70	1.9	2400	0.24	0.13	1.8	128
9 Citrus fruit	170	3	0.8	42.8	80	1.2	400	0.23	0.08	0.8	160
10 Tomatoes	120	5	1.6	25.5	50	2.7	5000	0.24	0.19	3.2	86
11 Other vegetables and fruit	210	4	1.6	50.9	70	2.0	1200	0.15	0.16	1.6	33
12 Fruit, fresh, canned and frozen	215	2	1.6	54.4	40	1.6	1600	0.13	0.13	1.3	28
13 Fruit, dried	1145	11	2.6	301.8	320	14.5	3800	0.51	0.50	5.7	9
14 Vegetables	155	6	1.6	33.9	90	2.1	500	0.17	0.19	1.9	41
15 Potatoes, sweetpotatoes	330	8	0.5	75.2	50	2.7	2200	0.40	0.15	4.3	65
16 Dry beans and peas, nuts	1920	104	85.7	211.7	600	24.7	100	2.56	0.93	26.2	5
17 Dairy products excluding butter (milk equivalent)	300	16	16.8	20.8	530	0.4	700	0.14	0.74	0.4	5
18 Non-fat solids (skim)	1645	162	4.5	236.1	5900	2.6	200	1.60	8.88	5.2	32
19 Milk, fluid whole	310	16	17.7	22.2	540	0.3	700	0.16	0.78	0.5	6
20 Cheese, all kinds	1350	105	98.7	9.4	2350	3.5	4300	0.10	1.74	0.2	0
21 Flour and cereal products, including enrichment	1650	47	5.7	346.7	80	10.2	100	1.41	0.79	11.5	0
22 Bread, white enriched (4% non-fat milk solids)	1245	39	14.5	235.2	360	8.0	0	1.10	0.70	10.0	0
23 Fats and oils, including bacon and salt pork	3540	11	391.0	1.6	35	1.0	3700	0.45	0.13	2.2	0
24 Butter and margarine	3260	3	367.7	1.8	90	0	15,000	0	0	0	0
25 Other, excluding bacon and salt pork	4045	0	454.0	0	0	0	0	0	0	0	0
26 Sugars and sirups	1695	Trace	0	437.7	35	2.1	0	Trace	0.01	0.1	Trace

/1/ Nutritive values used in basic computations are from Watt, B. K., and Merrill, A. L., U. S. Dept. Agr. Handbook 8, 1950. Except for eggs, non-fat milk solids (skim), fluid whole milk and white bread, enriched, these average nutritive values per pound are weighted by the relative quantities of foods within each of the groups estimated by the Agricultural Economics Division, Agricultural Marketing Service, as disappearing during 1952 into retail channels for civilian consumption. No deductions have been made for losses during cooking except those taken into account in Handbook 8, as, for example, in canned vegetables.

163. NUTRIENTS: SELECTED SOURCES

Foods listed are important sources of nutrients indicated. Values are per 100 grams of edible portion of fresh uncooked food, unless otherwise specified.

Nutrient	Sources and Nutritive Value	Nutrient	Sources and Nutritive Value
1 Food energy, Cal	Cheese (except cottage): 300-400; cooking and table fats, salad oils: 700-900; grain products, dry: 330-390; treenuts and peanut: 560-700; salt pork, bacon, and other fat meats: 600-800; sugars: 370-385.	10 Tocopherol, mg	Bean, navy, dry: 3.6; butter: 2.4; margarine: 54; egg, whole: 2; corn oil: 87; peanut oil: 22; soybean oil: 140.
2 Protein, g	Egg: 13; grains: 8-14; legumes, dry, mature: 21-35; meat, poultry, fish: 16-20; milk: 3-4.	11 Folic acid, µg	Asparagus: 89-142; broccoli: 34; bean, navy, dry: 129; corn, sweet: 9-70; cheese, cottage: 21-46; date, dry: 25; greens: collards, kale, mustard: 20-115; liver: 220-290; nuts: 27-77.
3 Carbohydrate, g	Fruit, dried: 67-73; grains: 70-80; legumes, dry, mature (except soybean): 60-64; potato, sweetpotato: 19-28; sugars: 90-100.	12 Vitamin K, µg	Cabbage, cauliflower: 250-275; liver, pork: 115-230; oats: 75; soybean: 190; spinach: 334; wheat bran: 80.
4 Fat, g	Cheese (except cottage): 25-37; cooking and table fats, salad oils: 81-100; cream: 20-35; nuts: 54-75; salt pork, bacon, other fat meats: 55-85.	13 Niacin, mg	Beef, lamb, pork: 2.6-5.2; fish ³ , poultry, veal: 5.6-10.5; liver, all kinds: 13.7-16.9; peanut: 16.2; wheat, other grain products, whole or enriched: 2-5.
5 Vitamin A, I.U.	Butter, margarine: 3300; carrot: 12,000; greens, all kinds: 3000-9500; liver, all kinds: 14,200-50,500; sweetpotato: 7700.	14 Pantothenic acid, mg	Bean, lima, dry: 0.8; kidney, lamb: 4.3; broccoli: 1.4; mushroom: 1.7; brains, beef: 2.1-2.9; egg: 2.7; liver, beef and pork: 5.7-8.2; peanut, roasted: 2.5; wheat bran: 2.4.
6 Ascorbic acid, mg	Various berries: 16-60; citrus fruit: 40-50; cantaloupe, honeydew: 23-33; green pepper: 120; broccoli, cabbage, cauliflower: 50-118; greens: collards, kale, mustard, turnip: 100-136; spinach: 59; potato, sweetpotato: 17-22; tomato: 23.	15 Pyridoxine, mg	Banana; cabbage; peanut, roasted; sweetpotato: 0.3; bean, lima, dry: 0.5; halibut: 0.1; liver, beef: 0.8; pork loin: 0.1-0.3; wheat, whole: 0.2; wheat germ: 0.6.
7 Choline, mg	Bean, snap: 340; pea: 260; egg yolk: 1130-1700; liver: 470-700; peanut: 160-170; soybean: 300-340; spinach: 240; wheat germ: 400.	16 Riboflavin, mg	Egg: 0.29; greens: collards, kale, turnip: 0.26-0.46; liver, all kinds: 2.46-3.96; meat, poultry: 0.12-0.26; milk: 0.17.
8 Vitamin B ₁₂	Liver and kidney: high; milk, muscle meats, fish: medium; corn, soybean, wheat, yeast: low.	17 Thiamine, mg	Legumes, dry, mature: 0.48-1.07; treenuts and peanut: 0.25-0.86; pork: 0.48-0.80; brown rice, rye, corn: 0.32-0.43; whole wheat, oatmeal: 0.40-0.60.
9 Vitamin D, I.U.	Egg yolk, dried: 265; fish ¹ : pilchard: 745; salmon: 314; sardine: 1379; fish ² : herring: 315; mackerel: 1100; shrimp: 150; liver, all kinds: 8-58.	18 Calcium, mg	Cheese: cheddar type: 670-925; fish, canned with edible bone: 150-400; greens: collard, kale, mustard, turnip: 220-259; milk: 118; soybean, and soyflours: 195-265.
		19 Iron, mg	Egg yolk: 7.2; greens: collards, kale, mustard, spinach, turnip: 1.6-3.0; legumes, dry: 4.7-8.0; liver, all kinds: 6.6-18.0; wheat: 3.0-4.3.

/1/ Canned. /2/ Raw, fresh. /3/ Includes Atlantic mackerel, halibut, salmon, swordfish.

164. DAILY DIETARY ALLOWANCES: MAN, U.S.A.

Allowances are designed for the maintenance of good nutrition of healthy persons normally vigorous and active, living in a temperate climate.¹

Group	Age yr	Weight kg (lb)	Height cm (in.)	Calories ²	Protein ³ g	Vitamin A I. U.	Ascorbic Acid mg	Vitamin D ⁴ I. U.	Niacin ⁵ mg	Ribo- flavin ⁶ mg	Thia- mine ⁷ mg	Calcium g	Iron mg	Other Nutrients ⁸
1	25	65(143)	170(67)	3200	65	5000	75		16	1.6	1.6	0.8	12	+
2	45	65(143)	170(67)	2900	65	5000	75		15	1.6	1.5	0.8	12	+
3	65	65(143)	170(67)	2600	65	5000	75		13	1.6	1.3	0.8	12	+
4	25	55(121)	157(62)	2300	55	5000	70		12	1.4	1.2	0.8	12	+
5	45	55(121)	157(62)	2100	55	5000	70		11	1.4	1.1	0.8	12	+
6	65	55(121)	157(62)	1800	55	5000	70		10	1.4	1.0	0.8	12	+
7	Pregnant (3rd trimester)			Add 400	80	6000	100	400	15	2.0	1.5	1.5	15	+
8	Lactating (850 ml daily)			Add 1000	100	8000	150	400	15	2.4	1.5	2.0	15	+
9	1/12 to 3/12	6(13)	60(24)	kg x 120	kg x 3.5	1500	30	400	3	0.4	0.3	0.6	6	+
10	4/12 to 9/12	9(20)	70(28)	kg x 110	kg x 3.5	1500	30	400	4	0.7	0.4	0.8	6	+
11	10/12 to 1	10(22)	75(30)	kg x 100	kg x 100	1500	30	400	5	0.9	0.5	1.0	6	+
12	1-3	12(27)	87(34)	1200	40	2000	35	400	6	1.0	0.6	1.0	7	+
13	4-6	18(40)	109(43)	1600	50	2500	50	400	8	1.2	0.8	1.0	8	+
14	7-9	27(59)	129(51)	2000	60	3500	60	400	10	1.5	1.0	1.0	10	+
15	10-12	35(78)	144(57)	2500	70	4500	75	400	13	1.8	1.3	1.2	12	+
16	13-15	49(108)	163(64)	3200	85	5000	90	400	16	2.1	1.6	1.4	15	+
17	16-20	63(139)	175(69)	3800	100	5000	100	400	19	2.5	1.9	1.4	15	+
18	10-12	36(79)	144(57)	2300	70	4500	75	400	12	1.8	1.2	1.2	12	+
19	13-15	49(108)	160(63)	2500	80	5000	80	400	13	2.0	1.3	1.3	15	+
20	16-20	54(120)	162(64)	2400	75	5000	80	400	12	1.9	1.2	1.3	15	+

/1/ Recommended by the Food and Nutrition Board, National Research Council, 1953. These allowances can be attained with a variety of common foods, which also provide nutrient requirements less well known. The allowances should cover individual variations among normal persons as they live in the U. S. A. subjected to ordinary environmental stresses. /2/ Allowance must be adjusted to meet specific needs; the proper allowance is that which over an extended period will maintain body weight or rate of growth at the "healthy" level. Adjustment for weight: For men and women differing from the standard body sizes of 65 and 55 kilograms (143 and 121 lb), the following formulas are applicable: Cal. for men = $152(W^{.73})$, Cal. for women = $123.4(W^{.73})$, where W = body weight in kilograms. For example, allowances for 25-year-old men weighing 50, 60, 70, and 80 kilograms, respectively, would be 2600, 3000, 3400, and 3700 Calories. Women of the same age and weighing 40, 50, 60, and 70 kilograms would receive, respectively, 1800, 2100, 2400, and 2700 Calories. These calorie allowances are based on proper, not actual, body weight for a given height. Adjustment for activity: For normally vigorous daily activity, make no correction; for sedentary life, reduce Calories by 22%; for heavy work, add 20-25%; for heaviest work add 50%. Adjustment for climate: A 5 per cent increase or decrease in calorie allowance for every 10° C difference (decrease or increase) in mean external temperature from the reference base of 10° C is proposed. For example, add 2% to Calories for extreme northern U. S. A.; subtract 5% for southern U. S. A. /3/ Allowance of 1 gram per day per kilogram of body weight should be adjusted according to body weight. /4/ Little evidence for need for supplemental Vitamin D by vigorous adults leading a normal life; however, for night workers and others whose habits shield them from sunlight, the ingestion of small amounts of the vitamin is desirable. /5/ Calorie-correlated; allowance is ten times that for thiamine. /6/ Computed from protein allowance, using a factor of 0.025. /7/ Calorie-correlated; allowance provides 0.5 milligrams for each 1000 Calories for adults, but the thiamine intake should not fall below 1 milligram daily. /8/ Carbohydrates and fats are essential for energy, but recommended allowances cannot be formulated as yet. Water: the standard is one ml per Calorie of food; much of this is in prepared foods. Sodium, potassium, and chlorine: indispensable dietary constituents. Potassium is widespread and does not need consideration as a dietary adjunct. The average normal adult intake of NaCl, 7-15 g, more than meets the normal requirement; additional quantities may be required with increased sweating. Phosphorus: allowance should equal that for calcium in diets of children and of women during latter part of pregnancy and lactation; for other adults allowance should be approximately 1½ times that for calcium. Copper: 1-2 mg daily for adults; for infants and children 0.05 mg/kg body weight. Iodine: 0.002-0.004 mg/kg body weight. There is presumptive evidence that cobalt, magnesium, manganese, molybdenum and zinc may be essential. Vitamin B₆ (pyridoxine group): approximate allowance is 1-2 mg daily. Vitamin B₁₂ (cobalamin; cyanocobalamin): probably essential, but no requirement formulated. Folic acid (folic acid group): less than 1 mg daily should be sufficient for any nutritional need. Vitamin K: requirement for maintenance of normal blood prothrombin level is provided by the average diet. However, if supplementary K was not given mother antepartum (daily dose of 1 mg orally during last month of pregnancy), the newborn infant should receive a single dose of 1 mg. /9/ During the first month of life, allowances for many nutrients are dependent upon maturation of excretory and endocrine functions; therefore, no specific recommendations are given. From one month to one year the recommendations pertain to nutrients primarily from cow's milk.

165. DAILY DIETARY ALLOWANCES: MAN (CANADA, U. K. , U. S. A.)¹

Dietary standards of the three countries differ considerably in philosophy and objective. The Canadian standard represents "a nutritional floor beneath which maintenance of the health of the people cannot be assumed." The British standards "are believed to be sufficient to establish and maintain a good nutritional state in representative individuals of population groups." The American allowances² "represent not merely minimal needs of average persons, but nutrient levels selected to cover individual variations in a substantial majority of the population." All the allowances must be adjusted to the actual needs of the individual, particularly with respect to body weight, degree of activity, age and environment. The adult allowances are for normally healthy young adults living in a temperate climate and engaged in work requiring moderate activity. Canadian standards for children neither combine allowances for girls and boys, nor place children in age groups, nor treat children (age 16-20) differently from adults; however, for comparisons with U. K. and U. S. A. standards, rough averages have been made to arrive at the values shown in this table.

Group	Age yr	Weight kg	Calories ³	Protein ⁴ g	Vit. A ⁵ I. U.	Vit. C ⁶ mg	Vit. D I. U.	Niacin mg	Ribo-flavin mg	Thia-mine mg	Calcium g	Iodine mg	Iron mg	Phos-phorus g
Adult Male														
1 Can.		64	2900 ⁷	60	4600	30		8.5	1.4	0.9	0.65	0.15-0.30	6	0.65
2 U. K.		65	3000	82	5000	20		12	1.8	1.2	0.8	0.1	12	
3 U. S. A.	25	65	3200	65	5000	75		16	1.6	1.6	0.8	0.15-0.30	12	1.2
Adult Female														
4 Can.		55	2400 ⁷	55	4000	30		7.5	1.1	0.8	0.55	0.15-0.30	12	0.55
5 U. K.		56	2500	69	5000	20		10	1.5	1.0	0.8	0.1	12	
6 U. S. A.	25	55	2300	55	5000	70		12	1.4	1.2	0.8	0.15-0.30	12	1.2
Pregnancy														
7 Can.			2900	80	6000	30	400	9	1.3	1.0	1.55	0.15-0.30	15	1.55
8 U. K.			2750	96	6000	40	400-600	11	1.6	1.1	1.5	0.15	15	
9 U. S. A.			2700	80	6000	100	400	15	2.0	1.5	1.5	0.15-0.30	15	1.5
Lactation														
10 Can.			3400	80	6000	30	400	10.5	1.6	1.1	1.55	0.15-0.30	15	1.55
11 U. K.			3000	111	8000	50	800	14	2.1	1.4	2.0	0.15	15	
12 U. S. A.			3300	100	8000	150	400	15	2.5	1.5	2.0	0.15-0.30	15	2.0
Children														
1/12-9 yr														
13 U. K.	<1	8	800	28	1500	10	800	3	0.5	0.3	1		6	
14 U. S. A.	4/12-9/12	8	kg x 110	kg x 3.5	1500	30	400	4	0.7	0.4	0.8	kg x 0.003	6	0.8
15 Can.	1-3	12	1250	37	860	30	400-800	3.7	0.6	0.4	1		6	
16 U. K.	1-3	12	1300	46	1500	15	400	5	0.8	0.5	1	0.15	7	
17 U. S. A.	1-3	12	1200	40	2000	35	400	6	1.0	0.6	1.0	kg x 0.003	7	1.0
18 Can.	4-6	19	1625	38	1400	30	400	5	0.8	0.5	1		6	
19 U. K.	4-6	18	1600	56	1500	15	400	6	1	0.6	1	0.15	8	
20 U. S. A.	4-6	18	1600	50	2500	50	400	8	1.2	0.8	1.0	kg x 0.003	8	1.0
21 Can.	7-9	26	2025	49	1900	30	400	6	1.1	0.6	1		6	
22 U. K.	7-9	27	1950	68	1500	20	400	8	1.2	0.8	1	0.15	10	
23 U. S. A.	7-9	27	2000	60	3500	60	400	10	1.5	1.0	1.0	kg x 0.003	10	1.0
10-20 yr														
24 Can.	10-12	34/37	2400/2500	60/62.5	2400/2700	30/30	400	7.2/7.2	1.5/1.5	0.7/0.7	1/1		6	
25 U. K.	10-12	35/35	2450/2450	86/86	1500/1500	25/25	400	10/10	1.5/1.5	1/1	1.2/1.2	0.15	12	
26 U. S. A.	10-12	35/36	2500/2300	70/70	4500/4500	75/75	400	13/12	1.8/1.8	1.3/1.2	1.2/1.2	kg x 0.003	12	1.2/1.2
27 Can.	13-15	49/49	2950/2500	75/75	3500/3500	30/30	400	9/7.5	1.5/1.2	0.9/0.7	1.5/1.5		12	
28 U. K.	13-15	49/49	3150/2750	110/96	1500/1500	30/30	400	13/11	1.9/1.6	1.3/1.1	1.4/1.3	0.15	15	
29 U. S. A.	13-15	49/49	3200/2500	85/80	5000/5000	90/80	400	16/13	2.1/2.0	1.6/1.3	1.4/1.3	kg x 0.003	15	1.4/1.3
30 Can.	16-20	60/53	3500/2400	60/55	4300/3800	30/30	400	8.5/7.5	1.7/1.1	1.1/0.7	1.5/1.5		12	
31 U. K.	16-20	63/54	3400/2500	119/88	2500/2500	30/30	400	14/10	2.1/1.5	1.4/1.0	1.4/1.0	0.15	15	
32 U. S. A.	16-20	63/54	3800/2400	100/75	5000/5000	100/80	400	19/12	2.5/1.9	1.9/1.2	1.4/1.3	kg x 0.003	15	1.4/1.3

/1/ Canadian values were adapted from "Nutrition," a bulletin of the Canadian Council on Nutrition, Ottawa: King's Printer and Controller of Stationery, 1950, and from the Canadian Bulletin on Nutrition 3:No. 2, 1953. Values for U. K. were adapted from "Report of the Committee on Nutrition," London: British Medical Association, 1950, and "Report of the National Food Survey Committee," London: Her Majesty's Stationery Office, 1952. Values for U. S. A. were derived from "Recommended Dietary Allowances," Food and Nutrition Board, Washington: National Research Council, 1953. /2/ For further details see Table 164. /3/ Allowance must be adjusted for variations in body weight, activity, and climate. See Footnote 2, Table 164. /4/ Allowance should be adjusted for variations in body weight; the general standard is one gram of protein per kilogram of body weight. /5/ Canadian allowance is expressed as I. U. of carotene; one I. U. is equivalent to 0.0006 mg β -carotene. The British and American allowances are expressed as I. U. in a diet containing both carotene and preformed A (one I. U. preformed A alcohol = 0.0003 mg). /6/ Ascorbic acid. /7/ The work allowance for "moderate activity" included in the total calorie allowance is 800 Calories for men and 500 Calories for women. Deducting these figures from the total allowance will give the maintenance requirement.

166. SUMMARY OF DAILY NUTRIENT ALLOWANCES: VERTEBRATES

Values are for maintenance and normally vigorous activity of male, adult animals, and are per kg body weight per day, unless otherwise indicated.

Required (R); Not Required (R)														
Nutrients	Man U. S. A. 1 25 yr; 65 kg	Beef Cattle 2 800 kg	Dairy Cattle 2 900 kg	Dog 3	Fox 3 5.7 kg	Hamster 4 0.025 kg	Horse 2 635 kg	Monkey, Rhesus	Mouse 4 0.025 kg	Rat, White 0.30 kg	Sheep 2 79 kg	Swine 3 227 kg	Chicken 3, 5 1.82 kg	Fish, Rainbow Trout
1 Water, ml	49	47	R	R	R	R	R	R	180	R	70	R	110	
2 Calories ⁶ , metabolizable	49	32	28	75	122	645	43	160	500	115	51	45	150	
3 Total food or feed, g	10.8	15	14	20-35	25	150	19	40	120	50	31	15	51	50-60
4 Residue, g						4.8		7.2		R			R	
5 Protein ⁷ , g	1	0.8	0.7	3-4	5	32	0.8	28.4	40	R	1.1	2.1	7.7	7-8
6 Carbohydrate, g	8.5				R	105	9.1		70	R	12		25	1-5
7 Fat, g	1.1-1.4			1.3		11.2	0.4		20	R	0.33	R	1.2	1-3
8 Vitamin A, I.U. ⁸	77	150	150	100	50	1800	150	60	1000	17	150	135	215	R
9 Ascorbic acid, mg	1.1			R		R		4	R	R		R		20-40
10 Biotin, µg	R			R(?)		20	R	8	30	10			(?)	15-26
11 Choline, mg				33		640		40	200	40			56	4-8
12 Cobalamin, µg	R(?)			0.55		R(?)		(?)	4	R(?)	1.7	R		R(?)
13 Vitamin D, I.U. ⁹	R		R	6.6	R	270	6.6	12.8	100	R	8	3	25.6 ¹⁰	R(?)
14 Vitamin E, mg		R	R			4.0		2.0	5	1.2	0.3	R		R(?)
15 Folic acid group, µg	R(?)			8	5	320	R	80	500	R(?)			15	100-200
16 Inositol, mg				R		400		40	R(?)	R				20-40
17 Vitamin K, µg	R			R		4800		40	1000	R				R(?)
18 Niacin, mg	0.25			0.24	0.26	8.0	0.1	1.0	5	R		0.17		3-4
19 Pantothenic acid, mg	R			0.05	0.20	1.6	R(?)	0.8	10	0.36		0.15	0.28	1-1.3
20 Para-aminobenzoic acid, mg				R		160		12(?)	R	R				R(?)
21 Pyridoxine group, µg	15-31			25	30	1900	R	140	1000	40			150	200-300
22 Riboflavin, µg	25			45	50	2600	R	140	2000	100		40	130	400-700
23 Thiamine, µg	25			18	30	1300	R	140	1000	50		17		100-200
24 Calcium, mg	12	22	18	260	160		28	155	900	160-200	45	90	1150	R
25 Chlorine, mg	93	30	R	225	R		R	230	800	20	150	45	160	
26 Cobalt, µg	R(?)	2000	R	6			(?)	19	400	R	100			
27 Copper, µg	18	R	R	165			(?)	480	700	1000	2000	R		
28 Fluorine, mg								0.04	0.6	R(?)				
29 Iodine, µg	2-4	R	R	33			R	600	1300	8		<4	20	R
30 Iron, mg	0.18	R	R	1.3				5	30	5	R	R		
31 Magnesium, mg	R(?)	R	R	11			R	10	60	5		R		
32 Manganese, mg	R(?)	0.3	0.3	0.11				1.6	5	2		R	1.7	
33 Molybdenum	R(?)													
34 Phosphorus, mg	18	22	18	220	160		31	170	900	140-180	40	60	385	
35 Potassium, mg	R	R	R	220				135	600	60		55-110		
36 Sodium, mg	60	20	R	150	R			130	500	200	100	30	100	
37 Sulfur, mg	R	R	R				R	14		R ¹¹				
38 Zinc, mg	R(?)	R		0.11				0.9	0.3	R		R		

/1/ Values are daily dietary allowances calculated from those recommended by the Food and Nutrition Board, National Research Council, 1953. /2/ Values are daily nutrient allowances calculated from those recommended by the Committee on Animal Nutrition, Agricultural Board, National Research Council, 1949-50; a few values have been changed in accordance with revisions recommended by the Committee. /3/ Values are daily nutrient requirements calculated from those recommended by the Committee on Animal Nutrition, 1953-54; a few values have been changed in accordance with revisions recommended by the Committee. /4/ Young animal, sex not specified. /5/ Single comb white leghorn, laying. /6/ Kilocalories. /7/ Digestible. /8/ One I.U. = 0.0006 mg β-carotene. /9/ One I.U. = 0.025 µg calciferol. /10/ International Chick Units; one unit = 0.025 µg D₃ (7-dehydrocholesterol). /11/ Except as sulfur-containing amino acids.

167. VITAMINS, SUMMARY OF ESTIMATED DAILY ALLOWANCES: VERTEBRATES

Values are per kg body weight per day, unless otherwise indicated.

Animal	Condition ¹	Vitamin A I. U. ²	Ascorbic Acid mg	Biotin μg	Choline mg	Cobalamin μg	Required (R); Not Required (R).										
							Vitamin D I. U. ³	Vitamin E mg	Folic Acid Group μg	Inositol mg	Vitamin K μg	Niacin mg	Pantothenic Acid mg	Para-amino- benzoic Acid mg	Pyridoxin μg	Riboflavin μg	Thiamine μg
Cat ⁴	Growth ♂♀	135					19					2.3				320	50
	Maintenance ♂♀	85					12					1.4				190	30
Cattle, beef	Growth ♂♀	215		R ⁵	R	R ⁵	7	R			R(?)		R ⁵		R ⁵	27 ⁵	R ⁵
	Maintenance ♂♀	150						R									
	Pregnancy	215						R									
	Lactation	1000						R									
Cattle, dairy	Growth ♂♀	150		R ⁵	R	R ⁵	6.6	R			R(?)	R	R ⁵		R ⁵	30 ⁵	R ⁵
	Maintenance ♂♀	150					R	R									
	Pregnancy	260					R	R									
	Lactation	260					R	R									
Dog	Growth ♂♀	200	R		55	1.1	21		15	R	R	0.4	0.1	R	55	90	33
	Maintenance ♂♀	100	R(?)	R(?)	33	0.55	6.6		8	R	R	0.24	0.05	R	25	45	18
Fox	Growth ♂	135					R		14			0.74	0.56		80	140	80
	♀	100					R		12			0.63	0.50		70	120	70
	Maintenance ♂♀	50					R		5			0.26	0.20		30	50	30
Guinea pig	Growth ♂♀	R	100-200 ⁶	R(?)	1000-1500 ⁶		R(?)	60-120 ⁶	3000-6000 ⁶	R(?)	2000	10-20 ⁶	15-20 ⁶	R	R	3000 ⁶	6000-8000 ⁶
	Reproduction		100-200 ⁶	R(?)						R(?)	R						
Hamster	Growth ♂♀	1800	R	20	640	R(?)	270	4.0	320	400	4800	8.0	1.6	160	1900	2600	1300
Horse	Growth ♂♀	185		R			6.6		R			0.1	R(?)		R	R	R
	Maintenance ♂♀	150		R			6.6		R			0.1	R(?)		R	R	R
	Pregnancy	215		R			6.6		R			0.13	R(?)		R	R	R
	Lactation	215		R			6.6		R			0.13	R(?)		R	R	R
Mink	Growth ♂	165					R		20			0.98	0.80		100	200	100
	♀	180					R		22			1.11	0.89		130	220	130
	Maintenance ♂	135					R		15			0.78	0.63		90	150	90
	♀	165					R		21			1.0	0.79		120	210	120
Monkey	Growth and maintenance ♂♀	60	4	8	40	(?)	13	2	80	40	40	1	0.8	12(?)	140	140	140
Mouse	Growth ♂♀	1000	R	30	200	4	100	5	500	R(?)	1000	5	10	R	1000	2000	1000
Rabbit	Growth ♂♀		R					0.32				225 ⁵ (?)				R	
	Maintenance ♂♀		R									5 ⁶				R	
Rat, cotton	Growth ♂♀	1500	R	20	160		200		320	160		4.0	3.2	48	400	480	400
Rat, white	Growth ♂♀	17	R	10	80	0.4	R	3.0(?)	8.0	R	R(?)	R(?)	1.0	R	300	300	200
	Maintenance ♂♀	17	R	10	40	R(?)	R	1.2	R(?)	R	R	R	0.36	R	40	100	50
	Pregnancy	R	R	10	50	R(?)	R	1.5	R(?)	R	R(?)	R(?)	0.45	R	90	40	50
	Lactation	R	R	12	60	R	R	1.5	R(?)	R	R(?)	R(?)	0.45	R	70	20	50
Sheep	Growth ♂♀	215					8	0.3					R ⁵		R ⁵	R ⁵	R ⁵
	Maintenance ♂♀	150				1.7	8	0.3									
	Pregnancy	215				1.7	8	0.3									
	Lactation	235				1.7	8	0.3									
Swine	Growth ♂♀	75	R		R	0.5	9.2		R			0.5	0.45		<110	100	50
	Breeding ♂	135	R			R	3	R				0.17	0.15			40	17
	Lactation	250	R			R	5.6	R				0.31	0.27			70	30
Chicken ⁷	Growth ♂♀	350	R	12	175	1.2	26	2.6	70		52	3.5	1.23		380	380	240
	Laying	265	R	8	56		30		15				0.28		170	130	
	Breeding ♀	265	R	7	56	0.2	30		21			0.45	0.55		170	230	
Duck	Growth ♂♀						220 ⁶					55 ⁶	11 ⁶		3 ⁶	4 ⁶	
Turkey ⁸	Growth ♂♀	400	R		125		68		70		100	3.7	0.83		260	280	
	Breeding ♀	165	R				28		200				0.42		110		
Trout ⁹	Maintenance	R	20-40	15-26	4-8	R(?)	R(?)	R(?)	100-200	20-40	R(?)	3-4	1-1.3	R(?)	200-300	400-700	100-200

/1/ Values for growth are for very young animals (i.e., about 1/4 grown). Maintenance values are for adults. /2/ One I.U. = 0.0006 mg β-carotene. /3/ One I.U. = 0.025 μg calciferol. Requirements for poultry expressed in International Chick Units. /4/ Diet of raw, unprocessed feed. Values are rough approximations, and may be inadequate for proper maintenance. /5/ Required only until vitamin is synthesized in the rumen. /6/ Per kilogram of feed. /7/ Single comb white leghorn. /8/ Broad-breasted bronze turkey. /9/ Rainbow trout.

168. DAILY NUTRIENT ALLOWANCES: BEEF AND DAIRY CATTLE

Data are from Reports no. III and IV, Committee on Animal Nutrition, National Research Council, 1950. Based on air-dry feed containing 90% dry matter. Allowances are probably higher than minimum requirements. Bf = beef cattle; Dr = dairy cattle.

Specifications	Heifers and Steers								Bulls				Cows					
	Growth								Maintenance ¹				Maintenance				Lactating	
	Bf	Dr ²	Bf	Dr ²	Bf	Dr ²	Bf	Dr ²	Bf	Dr	Bf	Dr	Bf ³	Dr	Bf ³	Dr	Bf ⁴	Dr ⁵
1 Weight, lb	400		600		800		1000		1200		1800	2000	800		1200		1000	
2 Expected daily gain, lb	1.6	1.8	1.4	1.4	1.2	1.2	1.0	1.3	1.4		1.5		1.5		1.8		2.8	
3 Total feed, lb	12	11	16	15	19	19	21	22	22	18	26	27	22	14	18	18	28	
4 Digestible protein, lb	0.9	0.8	0.9	0.85	0.9	0.9	0.9	0.95	1.4	1.0	1.4	1.45	1.0	0.5	0.8	0.7	1.4	2.4
5 TDN ⁶ , lb	7.0	6.5	8.5	8.5	9.5	10.0	10.5	11.0	13.0	10.3	14.0	15.6	11.0	6.8	9.0	9.2	14.0	20.8
6 Calcium ⁷ , g	20	20	18	18	16	16	15	15	21	12	18	20	22	8	16	12	30	50
7 Phosphorus ⁷ , g	15	15	15	15	15	15	15	15	18	12	18	20	18	8	15	12	24	38
8 Carotene ⁸ , mg	24	24	36	36	48	48	60	60	72	72	108	120	48	48	72	72	300	90
9 Vitamin D ⁹ , I.U.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

/1/ Moderate activity; breeding. /2/ Large breeds. /3/ Pregnant. /4/ Nursing calves, 3-4 months after parturition. /5/ Assuming 40 lb milk daily with 4% fat. /6/ Total digestible nutrients. /7/ Fe, Cu, I, Mg, Mn, Co, K, S, Na and Cl are probably essential, but quantitative requirements have not been defined. /8/ 0.0006 mg β -carotene = one I. U. /9/ Usually obtained in sufficient quantities from sunlight or sun-cured roughages. Young animals should be given 400 I. U. per 100 lb body weight.

169. DAILY NUTRIENT REQUIREMENTS: SWINE

Data are from Report no. II, Committee on Animal Nutrition, National Research Council, 1953.

Specifications	Market Stock							Pregnant ♀ and Breeding ♂		Lactating ♀	
								Young	Adult	Gilts	Adult
1 Weight, lb	25	50	100	150	200	250	300	500	350	450	
2 Expected daily gain, lb	0.8	1.2	1.6	1.8	1.8	1.8	0.75	0.5			
3 Total feed ¹ , lb	2.0	3.2	5.3	6.8	7.5	8.3	6.0	7.5	11.0	12.5	
4 TDN ² , lb	1.6 ³	2.4	4.0	5.1	5.6	6.2	4.5	5.6	8.3	9.4	
5 Crude protein, lb	0.36	0.51	0.74	0.88	0.9	1.0	0.90	1.05	1.65	1.75	
6 Calcium ⁴ , g	7.3	9.4	15.6	17.0	18.7	20.7	16.3	20.4	30.0	34.0	
7 Phosphorus ⁴ , g	5.4	6.5	10.8	10.2	11.2	12.4	10.9	13.6	20.0	22.7	
8 Sodium, as NaCl, g	4.5	7.3	12.0	15.4	17.0	18.8	13.6	17.0	25.0	28.4	
9 Vitamin B ₁₂ ⁵ , µg	20.0	16.0	26.5								
10 Carotene ⁶ , mg	0.5	1.0	2.0	3.0	4.0	5.0	15.0	18.7	27.5	31.2	
11 Choline, mg	800.0										
12 Vitamin D, I.U.	180.0	288.0	477.0	612.0	675.0	747.0	540.0	675.0	990.0	1125.0	
13 Niacin, mg	16.0	19.2	26.5	34.0	37.5	41.5	30.0	37.5	55.0	62.5	
14 Pantothenic acid, mg	10.0	16.0	23.8	30.6	33.8	37.4	27.0	33.8	49.5	56.2	
15 Pyridoxine, mg	1.2	1.9									
16 Riboflavin, mg	2.4	3.2	5.3	6.8	7.5	8.3	7.2	9.0	13.2	15.0	
17 Thiamine, mg	1.0	1.6	2.6	3.4	3.8	4.2	3.0	3.8	5.5	6.2	

/1/ Air-dried. /2/ Total digestible nutrients (75% TDN). /3/ For young pigs a high energy diet (80% TDN) is recommended. /4/ Fe, Cu, I, Mg, Co, K and Zn are probably essential, but quantitative requirements have not been defined. /5/ Cobalamin; cyanocobalamin. /6/ 0.0006 mg β -carotene = one I. U.

170. DAILY NUTRIENT REQUIREMENTS: CHICKEN

Data are from Report no. I, Committee on Animal Nutrition, National Research Council, 1954. Wh = single-comb white leghorn or similar breeds; Hb = heavy breeds.

Specifications	Growth												Laying ¹		Breeding ¹	
	Wh	Hb	Wh	Hb	Wh	Hb	Wh	Hb	Wh	Hb	Wh	Hb	Wh	Hb	Wh	Hb
1 Age, wk	3-4	3	5-6	5	7-8	5,7	10-11	8-9	11-14	10-11	14-18	12	36-52		36-52	
2 Weight, lb	0.5	0.5	1.0	1.0	1.5	1.5	2.0	2.0	2.5	3.0	3.0	4.5	4.0	5.5	4.0	5.5
3 Total feed, lb	0.067	0.062	0.097	0.103	0.117	0.131	0.156	0.181	0.175	0.240	0.168	0.192	0.241	0.276	0.241	0.276
4 Crude protein, lb	0.013	0.012	0.019	0.021	0.019	0.026	0.025	0.029	0.028	0.038	0.027	0.031	0.036	0.041	0.036	0.041
5 Calcium, g	0.30	0.281	0.44	0.468	0.53	0.595	0.71	0.822	0.80	1.09	0.76	0.872	2.46	2.82	2.46	2.82
6 Iodine, mg	0.033	0.031	0.049	0.051	0.023	0.065	0.031	0.036	0.035	0.048	0.034	0.038	0.048	0.055	0.121	0.138
7 Magnesium, mg	14.7	13.6	21.3	22.7	?	28.8	?	?	?	?	?	?	?	?	?	?
8 Manganese, mg	1.68	1.55	2.43	2.58	?	3.28	?	?	?	?	?	?	?	?	3.62	4.14
9 Phosphorus, g	0.18	0.169	0.26	0.281	0.32	0.357	0.43	0.493	0.48	0.654	0.46	0.523	0.66	0.75	0.66	0.75
10 Potassium, mg	61	56	88	94	85	119	113	131	127	174	122	139	?	?	?	?
11 Vitamin A, I. U. ⁴	80.0	74.0	116.0	124.0	140.0	157.0	187.0	217.0	210.0	288.0	202.0	230.0	482.0	552.0	482.0	552.0
12 Biotin, µg	2.7	2.5	3.9	4.1	?	5.2	?	?	?	?	?	?	?	?	?	?
13 Choline, mg	40.0	37.0	58.0	62.0	?	78.6	?	?	?	?	?	?	?	?	?	?
14 Vitamin D, I.C.U. ⁵	6.0	5.6	8.7	9.3	10.5	11.8	14.0	16.3	15.8	21.6	15.1	17.3	54.2	62.1	54.2	62.1
15 Folicin, µg	16.8	15.5	24.3	25.8	?	33	?	?	?	?	?	?	27	30	39	44
16 Niacin, mg	0.80	0.74	1.16	1.24	?	1.57	?	?	?	?	?	?	?	?	?	?
17 Pantothenic acid, mg	0.28	0.26	0.41	0.43	0.49	0.55	0.66	0.76	0.74	1.01	0.71	0.81	0.51	0.58	1.01	1.16
18 Pyridoxine, mg	0.087	0.081	0.126	0.134	?	0.170	?	?	?	?	?	?	0.31	0.36	0.31	0.36
19 Riboflavin, mg	0.087	0.081	0.126	0.134	0.094	0.170	0.125	0.145	0.140	0.192	0.134	0.154	0.241	0.276	0.410	0.469
20 Thiamine, mg	0.054	0.050	0.078	0.082	?	0.105	?	?	?	?	?	?	?	?	?	?

/1/ 60% production. /2/ Value for maintenance is 0.156. /3/ Value for maintenance is 0.192. /4/ One I. U. = 0.3 µg A alcohol, or 0.6 µg β -carotene = one U. S. P. unit. /5/ Vitamin D₃ (7-dehydrocholesterol). 0.025 µg crystalline D₃ = one I. C. U. (International Chick Unit). Chickens and turkeys utilize D₂ (from irradiated ergosterol) poorly.

171. AMINO ACID REQUIREMENTS, AND COMPOSITION IN VARIOUS FOODS

Ranges, in parentheses, are estimate "c" of the 95% range (cf Introduction).

Essential (R); utilized (U).

Amino Acid	Requirements ¹						Composition							
	Man ² , Adult 70 kg	Rat ³ , Adult 0.15 kg	Chicken ⁴ , Young 0.25 kg	Dog ⁵ , Adult 7 kg	Swine ⁶ , Young 45 kg	Beef Muscle ⁷	Casein ⁷	Egg Albumin ⁷	Egg Powder ⁷	Peanut Flour ⁷	Wheat Gluten ⁷	Milk, Mature		
												Man	Cow	Sow
	grams per animal per day					grams per 100 grams protein						mg per 100 ml milk		
1 Alanine	U	U										35	75	
2 Arginine	U	U	R 0.47	R 0.49	R 6.1	6.42	3.72	5.31	5.43	7.41	3.30	51(28-67)	124(90-173)	316
3 Aspartic acid	U	U				9.33	6.93	9.76	9.40	8.52	3.38	116	166	
4 Citrulline	U													
5 Cystine ⁸	U	U	R? 0.13			1.34	0.38	2.64	2.00	0.95	2.12	29(20-41)	29(23-34)	
6 Glutamic acid	U	U				14.61	21.31	11.45	10.96	12.03	31.36	230	680	
7 Glycine	U	U	R 0.39			5.62	1.89	3.34	3.45	3.53	2.97	0	11	
8 Histidine	U	R 0.005	R 0.06	R 0.17	R 11.7	3.24	2.89	2.15	1.84	1.46	1.78	23(12-38)	80(51-130)	120
9 Hydroxypro- line	U													
10 Isoleucine	R 0.70	R 0.03	R 0.23	R 0.56	R 14.4	5.16	4.63	5.73	5.39	2.72	4.07	86(46-114)	212(159-290)	234
11 Leucine	R 1.08	R 0.02	R 0.54	R 0.77	R 23.4	7.79	9.53	7.79	7.87	4.65	6.45	161(72-228)	356(240-400)	443
12 Lysine	R 0.80	R 0.009	R 0.35	R 0.42	R 29.2	8.58	7.71	6.39	5.35	2.29	1.81	79(50-111)	257(184-382)	408
13 Methionine	R 1.08	R 0.01	R 0.17	R 0.49	R 17.6	2.70	3.09	3.69	2.81	0.55	1.49	23(6-36)	87(50-140)	75
14 Phenylalanine	R 1.08	R 0.007	R 0.35	R 0.46	R 26.1	3.88	5.15	5.27	4.93	3.23	4.52	64(30-77)	173(111-228)	192
15 Proline	U					5.13	12.72	3.81	3.91	3.26	12.66	80	250	
16 Serine	U											69	160	
17 Threonine	R 0.49	R 0.01	R 0.23	R 0.38	R 11.7	4.44	4.28	4.33	4.31	1.83	2.51	62(40-76)	152(115-220)	750
18 Tryptophan	R 0.24	R 0.005	R 0.08	R 0.10	R 5.8	1.01	0.91	1.02	0.99	0.51	0.69	22(13-31)	50(36-80)	200
19 Tyrosine ⁹	U		R? 0.27			2.95	4.90	2.96	3.09	1.90	2.50	62(47-78)	190(158-251)	
20 Valine	R 0.80	R 0.02	R 0.31	R 0.59	R 11.7	5.13	7.01	6.62	6.10	3.00	3.81	90(48-133)	228(171-321)	1150

/1/ Values are essentially minimum requirements; for man they probably should be doubled to represent a "safe" allowance for normal, healthy adults, and this may be true for the other species listed. /2/ Values for man represent the L-forms of the amino acids, except glycine. /3/ White rat. /4/ New Hampshire. /5/ Cocker spaniel. The amino acids for which values are given probably are required, although the data available do not show this clearly. /6/ Synthetic diet with amino acids and diammonium citrate as nitrogen sources. /7/ Ash and moisture-free basis for partially purified proteins. /8/ Will replace about 1/2 of the methionine requirement. /9/ Will replace a portion of the phenylalanine requirement.

172. AMINO ACID REQUIREMENTS: INSECTS, BACTERIA

Required (R); not required (R).

Amino Acid		Insects ¹						Bacteria ²													
		Cockroach, German; nymph ³	Beetle, carpet; larva ⁴	Beetle, confused flour; larva ⁵	Fly, fruit, vinegar; larva ⁶	Mosquito, yellow-fever; larva ⁷	Parasite, spruce budworm; larva ⁸	Aerobacter aerogenes	Bacillus anthracis	B. licheniformis	B. megatherium	B. subtilis	Brucella suis	Erwinia amylovora	Escherichia coli	Lactobacillus arabinosus	Leuconostoc mesenteroides	Pasteurella tularensis	Salmonella typhosa	Serratia marcescens	Shigella sonnei
1	Alanine	R ⁹	R	R	R	R	R	R		R	R	R	R	R	R	R	R			R	R
2	Arginine	R ⁹	R	R	R	R	R	R		R	R	R	R	R	R	R	R			R	R
3	Aspartic acid	R ⁹	R	R	R	R	R	R													
4	Citrulline								R	R	R	R	R	R	R	R	R			R	R
5	Cystine	R ⁹	R	R	R	R	R?	R	R	R	R	R	R	R	R	R	R	R		R	R
6	Glutamic acid	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R			R	R
7	Glycine	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R			R	R
8	Histidine	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R			R	R
9	Hydroxyproline	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R			R	R
10	Isoleucine	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R			R	R
11	Leucine	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R			R	R
12	Lysine	R	R	R	R	R	R	R	R	R	R	R	R	R	R?	R	R			R	R
13	Methionine	R ⁹	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R			R	R
14	Norleucine		R	R	R				R	R	R	R	R	R	R	R	R			R	R
15	Phenylalanine	R	R	R	R	R?	R	R		R	R	R	R	R	R	R	R			R	R
16	Proline	R ^{9,10}	R	R	R	R			R	R	R	R	R	R	R	R	R			R	R
17	Serine	R ^{9,10}	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R			R	R
18	Threonine	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R			R	R
19	Tryptophan	R?	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R		R	R	R
20	Tyrosine	R	R	R	R	R?			R	R	R	R	R	R	R	R	R			R	R
21	Valine	R ⁹	R	R	R	R		R	R	R	R	R	R	R	R	R	R			R	R
22	Other am. acids ¹¹																	R	R		
23	Other N source ¹²							R		R	R	R	R	R	R	R	R			R	R

/1/ Diets containing all amino acids produce slightly better growth than mixtures of "required" acids alone. L-forms are biologically active, but the D-forms may be active for some species. See Table 173 for amino acid requirements of some additional species. /2/ There is wide variation in requirements among strains of a given species. /3/ *Blattella germanica* (L.). /4/ *Attagenus* (sp.). /5/ *Tribolium confusum* Duv. /6/ *Drosophila melanogaster* Meig. /7/ *Aedes aegypti* (L.). /8/ *Pseudosarcophaga affinis* (Fall.). /9/ Synthesized under aseptic conditions but at a rate insufficient for normal growth and/or development. /10/ Required by males only. /11/ Unspecified. /12/ NH₃, etc.

173. NUTRIENT UTILIZATION AND REQUIREMENTS: INSECTS

All insect tissues, and diets, contain nitrogen, carbon, oxygen and hydrogen. In addition, phosphorus, sulfur, iron, copper, magnesium, manganese, potassium, calcium and chlorine are probably universally required by insects. A number of other minerals, some only in traces, are consumed and found in the composition of the insect.

R = required; R = not required; U = utilized; U = not utilized; u = poorly utilized.

Nutrient	Value	Nutrient	Value	Nutrient	Value	Nutrient	Value
Bee, honey, adult (<i>Apis mellifera</i>)		Beetle, cigarette, larva (<i>Lasioderma serricorne</i>) (concluded)		Beetle, drug-store, larva ² (<i>Stegobium paniceum</i>) (concluded)		Beetle, spider, larva (<i>Ptinus tectus</i>) (concluded)	
1 Carbohydrates	U	80 Pyridoxine group	H(?)	157 Sorbose	U	232 Lipids, general	u
2 Arabinose	u	81 Riboflavin	R	158 Starch	U	233 Fatty acids	R
3 Cellobiose	u	82 Thiamine	R	159 Sucrose	U	234 Sterols, derivatives	R
4 Dextrin	U	Beetle, confused flour-, larva (<i>Tribolium con-</i> <i>fusum</i>)		160 Xylose	U	235 Calciferol	U
5 Fructose	U	83 Casein	U	161 Lipids, general	U	236 Cholesterol	u
6 Galactose	u	84 Gelatin	U	162 Fatty acids	R	237 Cholesterol	U
7 Glucose	U	85 Lactalbumin	U	163 Sterols, derivatives	R	238 Ergosterol	U
8 Inulin	U	86 Zein	U	164 Calciferol	U	239 Sitosterol	u
9 Lactose	R	87 Protein, total	15-45%	165 Cholesterol	U(?)	240 Zymosterol	U
10 Maltose	U	88 Alanine	R	166 Cholesterol	U	241 Biotin	R
11 Mannitol	U	89 Arginine	R	167 Ergosterol	U	242 Choline	R
12 Mannose	U	90 Aspartic acid	R	168 Sitosterol	U	243 Inositol	R(?)
13 Raffinose	U(?)	91 Cystine	R	169 Zymosterol	U	244 Niacin	R
14 Sorbitol	U	92 Glutamic acid	R	170 Biotin	R	245 Pantothenic acid	R
15 Sorbose	U	93 Glycine	R	171 Choline	R(?)	246 Para-aminobenzoic acid	H(?)
16 Starch	u	94 Histidine	R	172 Folic acid group	R	247 Pyridoxine group	R
17 Sucrose	U	95 Hydroxyproline	U	173 Inositol	R(?)	248 Riboflavin	R
18 Xylose	U(?)	96 Isoleucine	R	174 Niacin	R	249 Thiamine	R
Beetle, carpet, larva (<i>Attagenus</i> sp)		97 Leucine	R	175 Pantothenic acid	R	Blowfly, adult (<i>Calliphora erythrocephala</i>)	
19 Casein	U	98 Lysine	R	176 Para-aminobenzoic acid	R	250 Carbohydrates	U
20 Protein, total	6-12% ¹	99 Methionine	R	177 Pyridoxine group	R	251 Arabinose	U
21 Alanine	R	100 Phenylalanine	R	178 Riboflavin	R	252 Cellobiose	U
22 Arginine	R	101 Proline	U	179 Thiamine	R	253 Dextrin	u
23 Aspartic acid	R	102 Serine	R	Beetle, drug-store, adult (<i>Stegobium paniceum</i>)		254 Fructose	U
24 Cystine	R	103 Threonine	R	180 Biotin	R(?)	255 Galactose	U
25 Glutamic acid	R	104 Tryptophan	R	181 Choline	R(?)	256 Glucose	U
26 Glycine	R	105 Tyrosine	R	182 Folic acid group	R(?)	257 Inulin	U(?)
27 Histidine	R	106 Valine	R	183 Inositol	R	258 Lactose	u
28 Hydroxyproline	R	107 Carbohydrates	R(?)	184 Niacin	R	259 Maltose	U
29 Isoleucine	R	108 Arabinose	U	185 Pantothenic acid	R	260 Mannitol	U
30 Leucine	R	109 Cellobiose	U(?)	186 Para-aminobenzoic acid	R	261 Mannose	U
31 Lysine	R	110 Dextrin	U(?)	187 Pyridoxine group	R	262 Raffinose	U
32 Methionine	R	111 Fructose	U	188 Riboflavin	U	263 Sorbitol	U
33 Norleucine	R	112 Galactose	U	189 Thiamine	R	264 Sorbose	U
34 Phenylalanine	R	113 Glucose	U	Beetle, saw-toothed grain-, larva (<i>Oryzae-</i> <i>philus surinamensis</i>)		265 Starch	u
35 Proline	R	114 Inulin	U(?)	190 Gelatin	U	266 Sucrose	U
36 Serine	R	115 Lactose	U	191 Protein, total	45% ¹	267 Xylose	u
37 Threonine	R	116 Maltose	U	192 Carbohydrates	U	Cockroach, German, nymph (<i>Blattella germanica</i>) ⁴	
38 Tryptophan	R	117 Mannitol	U	193 Arabinose	U	268 Gelatin	U
39 Tyrosine	R	118 Mannose	U	194 Dextrin	U	269 Lactalbumin	U
40 Valine	R	119 Raffinose	U	195 Fructose	U	270 Zein	U
41 Carbohydrates	R	120 Sorbitol	U	196 Galactose	U	271 Protein, total	15-30%
42 Fatty acids	R	121 Sorbose	U	197 Glucose	U	272 Alanine	R
43 Sterols, derivatives	R	122 Sucrose	U	198 Inulin	U	273 Arginine	R
44 Cholesterol	U	123 Xylose	U	199 Lactose	U	274 Aspartic acid	R
45 Cholesterol	U	124 Lipids, general	U	200 Maltose	U	275 Cystine	R(?)
46 Ergosterol	u	125 Fatty acids	R	201 Mannitol	U	276 Glutamic acid	R
47 Biotin	R	126 Sterols, derivatives	R	202 Mannose	u	277 Glycine	R
48 Choline	R	127 Calciferol	U	203 Raffinose	U	278 Histamine	R
49 Folic acid group	R	128 Cholesterol	u(?)	204 Sorbitol	U	279 Hydroxyproline	R
50 Inositol	R	129 Cholesterol	U	205 Sorbose	U	280 Isoleucine	R
51 Niacin	R	130 Ergosterol	U	206 Starch	U	281 Leucine	R
52 Pantothenic acid	R	131 Sitosterol	U	207 Sucrose	U	282 Lysine	R
53 Para-aminobenzoic acid	R	132 Zymosterol	U	208 Xylose	U	283 Methionine	R(?)
54 Pyridoxine group	R	133 Biotin	R	209 Lipids, general	U	284 Phenylalanine	R
55 Riboflavin	R	134 Choline	R	210 Fatty acids	R	285 Proline	R
56 Thiamine	R	135 Folic acid group	R	211 Sterols, derivatives	R	286 Serine	R
Beetle, cigarette, larva (<i>Lasioderma serricorne</i>)		136 Inositol	R	212 Calciferol	U(?)	287 Threonine	R
57 Casein	U	137 Niacin	R	213 Cholesterol	U	288 Tryptophan	R(?)
58 Lactalbumin	U	138 Pantothenic acid	R	214 Cholesterol	U	289 Tyrosine	R
59 Protein, total	45% ¹	139 Para-aminobenzoic acid	R	215 Ergosterol	U	290 Valine	R
60 Carbohydrates	U-R	140 Pyridoxine group	R	216 Sitosterol	U	291 Carbohydrates	32% ³
61 Glucose	U	141 Riboflavin	R	217 Zymosterol	U	292 Dextrin	U
62 Starch	U	142 Thiamine	R	218 Biotin	U	293 Glucose	U
63 Sucrose	u(?)	Beetle, drug-store, larva ² (<i>Stegobium paniceum</i>)		219 Choline	U	294 Lactose	U
64 Lipids, general	U	143 Casein	U	220 Inositol	U	295 Starch	U
65 Fatty acids	R	144 Protein, total	45% ¹	221 Niacin	R	296 Sucrose	U
66 Sterols, derivatives	R	145 Carbohydrates	50% ³	222 Pantothenic acid	U	297 Lipids, general	U
67 Calciferol	U	146 Arabinose	U	223 Para-aminobenzoic acid	U	298 Fatty acids	R
68 Cholesterol	u	147 Fructose	U	224 Pyridoxine group	U	299 Sterols, derivatives	R
69 Cholesterol	U	148 Galactose	U	225 Riboflavin	R	300 Cholesterol	U
70 Ergosterol	U	149 Glucose	U	226 Thiamine	U	301 Biotin	R(?)
71 Sitosterol	U	150 Inulin	U	Beetle, spider, larva (<i>Ptinus tectus</i>)		302 Choline	R
72 Zymosterol	U	151 Lactose	U	227 Casein	U	303 Folic acid group	R
73 Biotin	R(?)	152 Maltose	U	228 Protein, total	45% ¹	304 Inositol	R
74 Choline	R(?)	153 Mannitol	U	229 Carbohydrates	U-R	305 Niacin	R
75 Folic acid group	R	154 Mannose	U	230 Glucose	u	306 Pantothenic acid	R
76 Inositol	R	155 Raffinose	U	231 Starch	U	307 Para-aminobenzoic acid	R
77 Niacin	R	156 Sorbitol	U			308 Pyridoxine group	R
78 Pantothenic acid	R(?)					309 Riboflavin	R
79 Para-aminobenzoic acid	R(?)					310 Thiamine	R

/1/ Per cent of protein in diet required to maintain growth and development. /2/ Deprived of normally present intracellular symbionts. /3/ Approximate percentage of carbohydrates required in optimum diet. /4/ Also aseptically reared on synthetic diet.

173. NUTRIENT UTILIZATION AND REQUIREMENTS: INSECTS (Concluded)

All insect tissues, and diets, contain nitrogen, carbon, oxygen and hydrogen. In addition, phosphorus, sulfur, iron, copper, magnesium, manganese, potassium, calcium and chlorine are probably universally required by insects. A number of other minerals, some only in traces, are consumed and found in the composition of the insect.

R = required; \bar{R} = not required; U = utilized; \bar{U} = not utilized; u = poorly utilized.

Nutrient		Value	Nutrient		Value	Nutrient		Value	Nutrient		Value
Fly, vinegar fruit-, larva (Drosophila melanogaster) ⁴			Mealworm, yellow, larva (Tenebrio molitor) (concluded)			Mosquito, larva (Aedes aegypti) ⁴ (concluded)			Moth, webbing clothes- (Timeola bisseliella) (concluded)		
311	Casein	U	380	Galactose	U	449	Calciferol	U			
312	Gelatin	U	381	Glucose	U	450	Cholestanol	U	515	Para-aminobenzoic acid	R
313	Protein, total	2-3%	382	Inulin	U	451	Cholesterol	U	516	Pyridoxine group	R
314	Alanine	R	383	Lactose	u	452	Ergosterol	u	517	Riboflavin	R
315	Arginine	R	384	Maltose	U	453	Sitosterol	U	518	Thiamine	R
316	Aspartic acid	R	385	Mannitol	U	454	Zymosterol	u	Parasite of spruce budworm larva (Pseudosarcophaga affinis) ⁴		
317	Cystine	R	386	Mannose	U	455	Biotin	R			
318	Glutamic acid	R	387	Raffinose	U	456	Choline	R			
319	Glycine	R	388	Sorbitol	U	457	Folic acid group	R	519	Amino acids, total	2% ⁵
320	Histidine	R	389	Sorbose	U	458	Inositol	R(?)	520	Alanine	R
321	Hydroxyproline	R	390	Starch	U	459	Niacin	R	521	Arginine	R
322	Isoleucine	R	391	Sucrose	U	460	Panthenic acid	R	522	Aspartic acid	R
323	Leucine	R	392	Xylose	u	461	Para-aminobenzoic acid	R(?)	523	Cysteine	R
324	Lysine	R	393	Lipids, general	U	462	Pyridoxine group	R	524	Glutamic acid	R
325	Methionine	R	394	Fatty acids	R	463	Riboflavin	R	525	Glycine	R
326	Phenylalanine	R	395	Sterols, derivatives	R	464	Thiamine	R	526	Histidine	R
327	Proline	R	396	Calciferol	U	Moth, Mediterranean flour-, larva (Ephestia kuehniella)			527	Hydroxyproline	R
328	Serine	R	397	Cholesterol	U						528	Isoleucine	R
329	Threonine	R	398	Ergosterol	U	465	Casein	U	529	Leucine	R
330	Tryptophan	R	399	Sitosterol	U	466	Protein, total	45% ¹	530	Lysine	R
331	Tyrosine	R	400	Biotin	R	467	Carbohydrates	80% ³	531	Methionine	R
332	Valine	R	401	Choline	R(?)	468	Dextrin	U	532	Phenylalanine	R
333	Carbohydrates	U	402	Folic acid group	R	469	Fructose	U	533	Proline	R
334	Arabinose	u	403	Inositol	R	470	Galactose	U	534	Serine	R
335	Cellobiose	U	404	Niacin	R	471	Glucose	U	535	Threonine	R
336	Dextrin	U	405	Panthenic acid	R	472	Inulin	U	536	Tryptophan	R
337	Fructose	U	406	Para-aminobenzoic acid	R	473	Lactose	U	537	Tyrosine	R
338	Galactose	u	407	Pyridoxine group	R	474	Maltose	U	538	Valine	R
339	Glucose	U	408	Riboflavin	R	475	Mannitol	U	539	Glutathione	R
340	Inulin	U	409	Thiamine	R	476	Raffinose	U	540	Carbohydrates	R
341	Maltose	U	Mosquito, larva (Aedes aegypti) ⁴			477	Sorbitol	U	541	Arabinose	u
342	Mannitol	u						478	Sorbose	U	542	Dextrin	U
343	Mannose	U	410	Casein	U	479	Starch	U	543	Galactose	U
344	Raffinose	U	411	Alanine	R	480	Sucrose	U	544	Glucose	0.5% ⁵
345	Sorbitol	U	412	Arginine	R	481	Xylose	U	545	Glycogen	U
346	Sorbose	U	413	Aspartic acid	R	482	Lipids, general	U	546	Lactose	u
347	Starch	u(?)	414	Cystine	R(?)	483	Fatty acids	R	547	Levulose	U
348	Sucrose	U	415	Glutamic acid	R	484	Sterols, derivatives	R	548	Maltose	U
349	Xylose	u	416	Glycine	R	485	Calciferol	U	549	Mannitol	u
350	Lipids, general	U	417	Histidine	R	486	Cholestanol	u(?)	550	Mannose	u
351	Fatty acids	R	418	Hydroxyproline	R	487	Cholesterol	U	551	Melezitose	U
352	Sterols, derivatives	R	419	Isoleucine	R	488	Ergosterol	u(?)	552	Raffinose	u
353	Calciferol	U	420	Leucine	R	489	Sitosterol	U	553	Rhamnose	u
354	Cholestanol	U	421	Lysine	R	490	Zymosterol	U	554	Sorbose	u
355	Cholesterol	U	422	Methionine	R	491	Biotin	R	555	Starch	U
356	Ergosterol	U	423	Phenylalanine	R(?)	492	Choline	R	556	Sucrose	U
357	Sitosterol	u	424	Proline	R	493	Folic acid group	R	557	Sorbitol	u
358	Biotin	R	425	Serine	R	494	Inositol	R	558	Trebalose	u
359	Choline	R	426	Threonine	R	495	Niacin	R	559	Xylose	u
360	Folic acid group	R	427	Tryptophan	R	496	Panthenic acid	R	560	Cholesterol	0.1% ⁵
361	Inositol	R	428	Tyrosine	R(?)	497	Para-aminobenzoic acid	R	561	Fatty acids	0.4% ⁵
362	Niacin	R	429	Valine	R(?)	498	Pyridoxine group	R	562	Ribonucleic acid	0.15% ⁵
363	Panthenic acid	R	430	Carbohydrates	U	499	Riboflavin	R	563	Biotin	R
364	Para-aminobenzoic acid	R	431	Arabinose	U	500	Thiamine	R	564	Choline	2.0mg ⁶
365	Pyridoxine group	R	432	Cellobiose	U(?)	Moth, webbing clothes- (Timeola bisseliella)			565	Folic acid group	R
366	Riboflavin	R	433	Fructose	U(?)						566	Inositol	R
367	Thiamine	R	434	Galactose	U(?)	501	Casein	U	567	Niacin	0.3mg ⁶
Mealworm, yellow, larva (Tenebrio molitor)			435	Glucose	U(?)	502	Protein, total	20-80% ¹	568	Panthenic acid	0.43mg ⁶
			436	Lactose	U(?)	503	Carbohydrates	U-R(?)	569	Para-aminobenzoic acid	R
368	Casein	U	437	Maltose	U(?)	504	Glucose	U	570	Pyridoxine	U
369	Gelatin	U	438	Mannitol	U(?)	505	Starch	U	571	Riboflavin	0.14mg ⁶
370	Lactalbumin	U	439	Mannose	U(?)	506	Lipids, general	U	572	Thiamine	0.1mg ⁶
371	Zein	U	440	Raffinose	U	507	Fatty acids	R	573	Vitamin B ₁₂	U
372	Protein, total	15-45% ¹	441	Sorbitol	U(?)	508	Sterols, derivatives	R	574	Galactose	u
373	Lysine	R	442	Sorbose	U	509	Cholesterol	U	575	Glucose	u
374	Tryptophan	R	443	Starch	U	510	Biotin	R(?)	576	Lactose	u
375	Carbohydrates	80-85% ³	444	Sucrose	U	511	Choline	R	577	Levulose	U
376	Arabinose	u	445	Xylose	u(?)	512	Inositol	R	578	Maltose	U
377	Cellobiose	u	446	Lipids, general	U	513	Niacin	R	579	Mannitol	u
378	Dextrin	U	447	Fatty acids	R	514	Panthenic acid	R	580	Raffinose	u
379	Fructose	U	448	Sterols, derivatives	R				581	Sucrose	U
									582	Xylose	u

/1/ Per cent of protein in diet required to maintain growth and development. /3/ Approximate percentage of carbohydrates required in optimum diet. /4/ Also aseptically reared on synthetic diet. /5/ Per cent in diet required to maintain optimum growth and development. /6/ mg/100 ml in diet required to maintain optimum growth and development.

174. NUTRIENT UTILIZATION: LOWER ALGAE AND RELATED COLORLESS ORGANISMS

Oxygen is essential for all organisms listed. Carbon dioxide is required by all species in this table for which data are available. Certain green forms, e.g., *Chlamydomonas moewusii* and *Anabaena cylindrica*, appear unable to grow in darkness. Colorless and green forms grown in darkness require an additional carbon source.

U = utilized; u = poorly utilized; U = not utilized; R = required; R = not required.

Nutrient	Photosynthetic Forms														Colorless Forms											
	<i>Chlamydomonas agloiformis</i>	<i>C. moewusii</i>	<i>Chlorogonium elongatum</i>	<i>C. eichlorum</i>	<i>Chlorella vulgaris</i> ¹	<i>Euglena anabaena minor</i>	<i>E. deses</i>	<i>E. gracilis typica</i>	<i>E. gracilis bacillaris</i>	<i>E. gracilis urophora</i>	<i>E. klebsii</i>	<i>E. pisciformis</i>	<i>E. stellata</i>	<i>Haematococcus pluvialis</i>	<i>Nitzschia closterium</i>	<i>Anabaena cylindrica</i> ²	<i>Astasia longa</i>	<i>A. quartana</i>	<i>Chilomonas paramecium klebsii</i>	<i>Hyalogonium caudatum</i>	<i>P. obtusum</i>	<i>P. ocellatum</i>	<i>P. uvella</i>	<i>Polytomella caeca</i>	<i>Prototheca zopfii</i>	
1 Cobalamin	R	R	R	R	R	R ³		R ⁴	R ⁴	R ⁴	R ^{3,7}	R	R ^{3,7}	R	R	R	R		R							
2 Thiamine	R	R	R	R	R	R ³		R	R	R	R ^{3,7}	R	R ^{3,7}	R	R	R	R		R		R	R	R	R	R	
3 Other	R	R	R	R	R	R ³																				
Vitamins																										
Carbon Source: Sugars																										
4 Arabinose		U	U?	U?	u	U		U	U	U	U					U	U		U?				U	U	U	
5 Glucose		U	U?	U?	u	U		U	U	U	U					U	U		U?			U	U	U	U	
6 Maltose		U	U?	U?	u	U		U		U	U					U	U		U?				U	U	U	
7 Sucrose		U	U?	U?	u	U		U		U	U					U	U		U?				U	U	U	
8 Xylose		U	U?	U?															U?				U	U	U	
Carbon Source: Organic Acids (Other than Fatty Acids) ⁵																										
9 Citric	U	U			u	U	U	U	U ⁶	U	U			U					U?			U	U	U	U	
10 Fumaric	U	U			u	U		U	U ⁶	U	U			U				U	U			U	U	U	U	
11 Lactic	U	U		U	u	U		U	U ⁶	U	U		U	U				U	U		U	U	U	U	U	
12 Malic	U	U		U	u	U		U	U ⁶	U	U		U	U				U?	U		U	U	U	U	U	
13 Phosphoglyceric	U	U		U	u	U		U	U ⁶	U	U		U	U				U?	U		U	U	U	U	U	
14 Pyruvic	U	U		U	u	U		U	U	U	U		U	U				U?	u		U	U	U	U	U	
15 Succinic	U	U		U	u	U		U	U ⁶	U	U?		U	U				U?	u		U	U	U	U	U	
Carbon Source: Alcohols ⁷																										
16 i-Butanol								U	U	U							u	U	U		U	U	U	U	U	
17 n-Butanol		U						U	U	U							u	U	U		U	U	U	U	U	
18 Ethanol		U		U				U	U	U							u	U	U		U	U	U	U	U	
19 Glycerol		U				U		U	U	U		U	U				u	U	U		U	U	U	U	U	
20 n-Hexanol								U	U	U							u	U	U		U	U	U	U	U	
21 Methanol								U	U	U							u	U	U		U	U	U	U	U	
22 i-Pentanol								U	U	U							u	U	U		U	U	U	U	U	
23 n-Pentanol								U	U	U							u	U	U		U	U	U	U	U	
24 i-Propanol								U	U	U							u	U	U		U	U	U	U	U	
25 n-Propanol								U	U	U							u	U	U		U	U	U	U	U	
Carbon Source: Fatty Acids ⁹																										
26 Acetic	U	U	U	U	u	U	U	U	U	U	U	U	U	U	U	U	U	u	U	U	U	U	U	U	U	
27 i-Butyric	U	U	U	U		U		U	U	U	U	U	U	U	U	U	U	u	U	U	U	U	U	U	U	
28 n-Butyric	U	U	U	U		U		U	U	U	U	U	U	U	U	U	U	u	U	U	U	U	U	U	U	
29 i-Caproic						U		U	U	U	U	U	U	U	U	U	U	u	U	U	U	U	U	U	U	
30 n-Caproic	U		U	U		U		U	U	U	U	U	U	U	U	U	U	u	U	U	U	U	U	U	U	
31 n-Decylic								U	U	U	U	U	U	U	U	U	U	u	U	U	U	U	U	U	U	
32 n-Heptylic						U		U	U	U	U	U	U	U	U	U	U	u	U	U	U	U	U	U	U	
33 n-Nonylic						U		U	U	U	U	U	U	U	U	U	U	u	U	U	U	U	U	U	U	
34 n-Octylic						U		U	U	U	U	U	U	U	U	U	U	u	U	U	U	U	U	U	U	
35 Propionic	U	U	U	U	u	U		U	U	U	U	U	U	U	U	U	U	u	U	U	U	U	U	U	U	
36 i-Valeric	U	U	U	U		U		U	U	U	U	U	U	U	U	U	U	u	U	U	U	U	U	U	U	
37 n-Valeric	U	U	U	U		U		U	U	U	U	U	U	U	U	U	U	u	U	U	U	U	U	U	U	
Nitrogen Sources ¹¹																										
38 D-Alanine	U	U	U	U	U	U	U	U ¹²	U ¹²	U ¹²	U	U ¹³	U	U	U	U	U				u	U	U	U	U	
39 Ammonium	U	U	U	U	U	U	U	U ¹²	U ¹²	U ¹²	U	U ¹³	U	U	U	U	U				u	U	U	U	U	
40 D-Arginine					U	U	U	U ¹²	U ¹²	U ¹²	U	U ¹³	U	U	U	U	U				u	U	U	U	U	
41 L-Asparagine	U ¹²	U		U ¹²	U	U	U	U ¹²	U ¹²	U ¹²	U	U ¹⁴	U	U	U	U	U				U	U	U	U	U	
42 D-Glutamic acid ¹⁵			U	U		U	U	U ¹²	U ¹²	U ¹²	U	U ¹³	U	U	U	U	U				U	U	U	U	U	
43 Glycine	U ¹²				U	U	U	U ¹²	U ¹²	U ¹²	U	U ¹³	U	U	U	U	U				U	U	U	U	U	
44 Histidine					U	U	U	U ¹²	U ¹²	U ¹²	U	U ¹³	U	U	U	U	U				U	U	U	U	U	
45 L-Leucine					U	U	U	U ¹²	U ¹²	U ¹²	U	U ¹³	U	U	U	U	U				U	U	U	U	U	
46 D-Lysine					U	U	U	U	U	U	U	U ¹³	U	U	U	U	U				U	U	U	U	U	
47 Nitrate	U	U	U	U ¹²	U	U	U	U	U	U	U	U ¹³	U	u	U ¹²	U	U				U	U	U	U	U	
48 Peptone	U ¹²				U	U	U	U ¹²	U ¹²	U ¹²	U	U	U	U	U	U	U				U	U	U	U	U	
49 D,L-Phenylalanine					U	U	U	U ¹²	U ¹²	U ¹²	U	U ¹³	U	U	U	U	U				U	U	U	U	U	
50 D,L-Proline					U	U	U	U ¹²	U ¹²	U ¹²	U	U ¹³	U	U	U	U	U				U	U	U	U	U	
51 D,L-Serine					U	U	U	U ¹²	U ¹²	U ¹²	U	U ¹³	U	U	U	U	U				U	U	U	U	U	
52 L-Tryptophan					U	U	U	U	U	U	U	U ¹³	U	U	U	U	U				U	U	U	U	U	
53 L-Tyrosine					U	U	U	U	U	U	U	U ¹³	U	U	U	U	U				U	U	U	U	U	
54 D,L-Valine					U	U	U	U ¹²	U ¹²	U ¹²	U	U ¹³	U	U	U	U	U				U	U	U	U	U	

/1/ Additional components not listed: fructose, U; galactose, u; lactose, U; mannose, u; inulin, u; methyl- γ -D-glucoside, u; methyl- β -D-glucoside, U; starch, u; cis-aconitic, u; inositol, u; mannitol, u; sorbitol, u; L-aspartic acid, u. /2/ Additional components not listed: mannitol, U; elementary nitrogen, U. /3/ The organism has been reported not to require vitamins; it is possible that this condition, as in other species of *Euglena*, exists only after adaptation to vitamin-less media. /4/ Pseudo-cobalamin also utilized. /5/ It has been shown that *Prototheca zopfii* and *Euglena gracilis* utilize most of these acids only at pH 3.5-5.5; the majority of the negative results tabulated may not be significant because they were obtained in media having a pH near neutrality. /6/ Utilized only at pH 3.0-5.5. /7/ Optimal concentrations are similar to those of the corresponding fatty acid (cf Fn 9). /8/ Inadequate for growth in mineral media. /9/ The following are average ranges of concentration (g per 100 ml media) at which fatty acids are utilized and non-toxic: acetic, propionic, butyric and isobutyric acids, 0.1-0.2; valeric and isovaleric acids 0.05-0.1; caproic, isocaproic, heptylic and octylic acids, 0.01-0.03; nonylic acid, 0.01; decylic acid, 0.005-0.008. Some negative results tabulated may be incorrect if toxic concentrations were employed. Toxicity usually increases with length of carbon chain and with decrease in pH of medium. /10/ Employed at toxic concentrations. /11/ For photosynthetic species data pertain to utilization in light. Some amino acids may serve also as carbon sources. /12/ Also utilized in darkness. /13/ Negative results may not be valid because tests were conducted in media lacking thiamine. /14/ Growth is obtained only if thiamine is present. /15/ When utilized, a good carbon source.

175. SUGAR UTILIZATION FOR GROWTH: FILAMENTOUS FUNGI

Interpretation of the amount of growth obtained on different sugars is often subject to error. Low yields may be attributed to slow utilization of the sugar involved, but are frequently caused by other factors. It is possible that some organisms listed as not utilizing a certain sugar, or utilizing it poorly will be found to utilize it well under different nutritional conditions. U = utilized; u = utilized slowly; \bar{U} = utilization slight or none.

Species													Species												
	p-Glucose	p-Fructose	p-Mannose	p-Galactose	L-Sorbose	L-Arabinose	p-Xylose	Maltose	Sucrose	Lactose	Cellobiose	Raffinose		p-Glucose	p-Fructose	p-Mannose	p-Galactose	L-Sorbose	L-Arabinose	p-Xylose	Maltose	Sucrose	Lactose	Cellobiose	Raffinose
1 Achlya flagellata	U	U	U	U	U	U	U	U	U	U	U	U	45 Melanconium fuligineum	U	U	U	U	U	U	U	U	U	U	U	
2 Allomyces sp	U	U	U	U	U	U	U	U	U	U	U	U	46 Memnoniella echinata	U	U	U	U	U	U	U	U	U	U	U	
3 Alternaria solani	U	U	U	U	U	U	U	U	U	U	U	U	47 Monilinia fructicola	U	U	U	U	U	U	U	U	U	U	U	
4 Aspergillus clavatus	U	U	U	U	U	U	U	U	U	U	U	U	48 Monosporium apiospermum	U	U	U	U	U	U	U	U	U	U	U	
5 A. elegans	U	U	U	U	U	U	U	U	U	U	U	U	49 Morchella esculenta	U	U	U	U	U	U	U	U	U	U	U	
6 A. niger	U	U	U	U	U	U	U	U	U	U	U	U	50 Mucor ramannianus	U	U	U	U	U	U	U	U	U	U	U	
7 A. oryzae	U	U	U	U	U	U	U	U	U	U	U	U	51 Neocosmospora vasinfecta	U	U	U	U	U	U	U	U	U	U	U	
8 A. rugulosus	U	U	U	U	U	U	U	U	U	U	U	U	52 Ophiobolus graminis	U	U	U	U	U	U	U	U	U	U	U	
9 Blakeslea trispora	U	U	U	U	U	U	U	U	U	U	U	U	53 Penicillium chrysogenum	U	U	U	U	U	U	U	U	U	U	U	
10 Blastocladiella pringsheimii	U	U	U	U	U	U	U	U	U	U	U	U	54 P. digitatum	U	U	U	U	U	U	U	U	U	U	U	
11 Botrytis cinerea	U	U	U	U	U	U	U	U	U	U	U	U	55 P. expansum	U	U	U	U	U	U	U	U	U	U	U	
12 Ceratostomella fibriata	U	U	U	U	U	U	U	U	U	U	U	U	56 P. spiculosporum	U	U	U	U	U	U	U	U	U	U	U	
13 Chaetomium convolutum	U	U	U	U	U	U	U	U	U	U	U	U	57 Phoma betae	U	U	U	U	U	U	U	U	U	U	U	
14 C. globosum	U	U	U	U	U	U	U	U	U	U	U	U	58 Phycomyces blakesleeanus	U	U	U	U	U	U	U	U	U	U	U	
15 Choanephora cucurbitarum	U	U	U	U	U	U	U	U	U	U	U	U	59 Phymatotriconia omnivorum	U	U	U	U	U	U	U	U	U	U	U	
16 Chytridium sp	U	U	U	U	U	U	U	U	U	U	U	U	60 Phytophthora cactorum	U	U	U	U	U	U	U	U	U	U	U	
17 Claviceps purpurea	U	U	U	U	U	U	U	U	U	U	U	U	61 P. erythrosetica	U	U	U	U	U	U	U	U	U	U	U	
18 Coccidioides immitis	U	U	U	U	U	U	U	U	U	U	U	U	62 P. fagopyri	U	U	U	U	U	U	U	U	U	U	U	
19 Colletotrichum lindemuthianum	U	U	U	U	U	U	U	U	U	U	U	U	63 P. infestans	U	U	U	U	U	U	U	U	U	U	U	
20 Collybia velutipes	U	U	U	U	U	U	U	U	U	U	U	U	64 Pilaira moreau	U	U	U	U	U	U	U	U	U	U	U	
21 Cordyceps militaris	U	U	U	U	U	U	U	U	U	U	U	U	65 Polyporus abietis	U	U	U	U	U	U	U	U	U	U	U	
22 Dendrophoma obscurans	U	U	U	U	U	U	U	U	U	U	U	U	66 P. versicolor	U	U	U	U	U	U	U	U	U	U	U	
23 Diaporthe phaseolorum batat.	U	U	U	U	U	U	U	U	U	U	U	U	67 Pythiogenon uniforme	U	U	U	U	U	U	U	U	U	U	U	
24 Dictyuchus monosporus	U	U	U	U	U	U	U	U	U	U	U	U	68 Pythiomorpha gonapodyoides	U	U	U	U	U	U	U	U	U	U	U	
25 Diplodia macrospora	U	U	U	U	U	U	U	U	U	U	U	U	69 Pythium ascophallon	U	U	U	U	U	U	U	U	U	U	U	
26 D. natalensis	U	U	U	U	U	U	U	U	U	U	U	U	70 Rhizophlyctis rosea	U	U	U	U	U	U	U	U	U	U	U	
27 Endoconidiophora fagacearum	U	U	U	U	U	U	U	U	U	U	U	U	71 Rhizopus nigricans	U	U	U	U	U	U	U	U	U	U	U	
28 Endothia parasitica	U	U	U	U	U	U	U	U	U	U	U	U	72 R. suinus	U	U	U	U	U	U	U	U	U	U	U	
29 Entomophthora apiculata	U	U	U	U	U	U	U	U	U	U	U	U	73 Rosellinia arcuata	U	U	U	U	U	U	U	U	U	U	U	
30 E. coronata	U	U	U	U	U	U	U	U	U	U	U	U	74 Saprolegnia delicata	U	U	U	U	U	U	U	U	U	U	U	
31 Fusarium conglutinans	U	U	U	U	U	U	U	U	U	U	U	U	75 S. ferax	U	U	U	U	U	U	U	U	U	U	U	
32 F. culmorum	U	U	U	U	U	U	U	U	U	U	U	U	76 Schizophyllum commune	U	U	U	U	U	U	U	U	U	U	U	
33 F. lycopersici	U	U	U	U	U	U	U	U	U	U	U	U	77 Schizothecium longicolle	U	U	U	U	U	U	U	U	U	U	U	
34 F. medicaginis	U	U	U	U	U	U	U	U	U	U	U	U	78 Sclerotium delphinii	U	U	U	U	U	U	U	U	U	U	U	
35 F. nivale	U	U	U	U	U	U	U	U	U	U	U	U	79 Septoria nodorum	U	U	U	U	U	U	U	U	U	U	U	
36 F. nivaeum	U	U	U	U	U	U	U	U	U	U	U	U	80 Sordaria fimicola	U	U	U	U	U	U	U	U	U	U	U	
37 F. tracheiphilum	U	U	U	U	U	U	U	U	U	U	U	U	81 Sphaeropsis malorum	U	U	U	U	U	U	U	U	U	U	U	
38 Glomerella cingulata	U	U	U	U	U	U	U	U	U	U	U	U	82 Stysanus stemonitis	U	U	U	U	U	U	U	U	U	U	U	
39 Helicostylum pyiforme	U	U	U	U	U	U	U	U	U	U	U	U	83 Syncephalastrum racemosum	U	U	U	U	U	U	U	U	U	U	U	
40 Helminthosporium sativum	U	U	U	U	U	U	U	U	U	U	U	U	84 Thielavia basicola	U	U	U	U	U	U	U	U	U	U	U	
41 Lenzites saeplaria	U	U	U	U	U	U	U	U	U	U	U	U	85 Thraustotheca clavata	U	U	U	U	U	U	U	U	U	U	U	
42 L. trabaea	U	U	U	U	U	U	U	U	U	U	U	U	86 Typhula variabilis	U	U	U	U	U	U	U	U	U	U	U	
43 Leptomitius lacteus	U	U	U	U	U	U	U	U	U	U	U	U	87 Ustilago violacea	U	U	U	U	U	U	U	U	U	U	U	
44 Macrochytium sp	U	U	U	U	U	U	U	U	U	U	U	U													

176. ORGANIC COMPLEXES REQUIREMENTS: BACTERIA

R = required; \bar{R} = not required.

		R = required; R = not required.															
Species		Vitamin A	Ascorbic Acid	Biotin	Choline	Cobalamin	Vitamin D	Vitamin E	Folic Acid	Inositol	Vitamin K	Niacin	Pantothenic Acid	Para-aminobenzoic Acid	Pyridoxine Group ¹	Riboflavin	Thiamine
1	Aerobacter aerogenes	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
2	Bacillus alvei			R								R				R	
3	B. anthracis			R								R				R	
4	B. brevis			R								R				R	
5	B. cereus			R								R				R	
6	B. cereus mycoides			R								R				R	
7	B. circulans			R								R				R	
8	B. coagulans			R								R ²				R	
9	B. licheniformis			R								R				R	
10	B. macerans			R								R				R	
11	B. megaterium			R?								R?				R	
12	B. pasteurii			R?								R				R	
13	B. polymyxa			R								R				R	
14	B. pumilis			R?								R				R	
15	B. sphaericus			R								R				R	
16	B. subtilis			R								R				R	
17	B. subtilis niger			R								R				R	
18	Brucella abortus	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
19	B. melitensis	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
20	B. suis	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
21	Erwinia amylovora	R	R	R	R	R	R	R	R	R	R	R ³	R	R	R	R	R
22	E. tracheiphila	R	R	R	R	R	R	R	R	R	R	R ³	R	R	R	R	R
23	Escherichia coli	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
24	Hemophilus influenzae ⁴	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	Lactobacillus																
25	Hetero-fermentative ⁵			R		R ^{3,6}			R ^{3,7}			R	R	R ^{3,7}	R ^{3,7}	R	R
26	Homo-fermentative ⁵			R		R ^{3,6}			R ^{3,7}			R	R	R ^{3,7}	R ^{3,7}	R	R
27	Leuconostoc citrovorum			R					R ^{3,7}			R ⁸	R	R ⁸	R ^{7,9}	R ^{7,9}	R ^{7,9}
28	L. dextranicum			R					R			R ⁸	R	R ⁸	R ^{7,9}	R ^{7,9}	R ^{7,9}
29	L. mesenteroides			R					R			R ⁸	R	R ⁸	R ^{7,9}	R ^{7,9}	R ^{7,9}
30	Pasteurella multocida ¹⁰			R ³								R ¹¹	R			R	
31	P. pseudotuberculosis	R	R	R		R		R	R	R		R		R		R	R ¹
32	P. tularensis			R								R		R		R	
33	Proteus morgani											R	R			R	
34	P. vulgaris											R				R	
35	Salmonella cholerae-suis	R	R	R		R		R	R		R	R	R	R	R	R	R
36	S. enteritidis	R	R	R		R		R	R		R	R	R	R	R	R	R
37	S. gallinarum			R								R		R		R	R
38	S. pullorum	R	R	R		R		R	R		R	R ³	R	R	R	R	R
39	S. schottmuelleri	R	R	R								R	R	R	R	R	R
40	S. typhosa	R	R	R		R		R	R		R	R	R	R	R	R	R
41	Serratia marcescens	R	R	R		R		R	R		R	R	R	R	R	R	R
42	Shigella alkalescens		R	R		R		R				R		R		R	R
43	S. paradyseuteriae											R ¹³	R ³	R ³			
44	S. sonnei											R ¹³	R ³	R ³			
45	Staphylococcus albus											R	R	R	R	R	R
46	S. aureus		R									R	R	R	R	R	R

23/ *Escherichia coli* R R K R K R K R K R K R K S. aureus R R R R R R R R R R R R R R
[1] Includes pyridoxine, pyridoxal, pyridoxamine. [2] One strain only. [3] Various strains. [4] Requires hemin, diphosphopyridine. H.para influenzae requires diphosphopyridine nucleotide, putrescine. [5] Some strains also require pyridoxal phosphate, pantothenic acid. [6] Or nucleotides. [7] Occasional requirement as growth stimulant. [8] Nicotinic acid for some strains only. [9] Occasional requirement for growth. [10] For P. pestis: only hemin required for aerobic types; no known requirements for anaerobic types. [11] Nicotinamide. [12] Thiamine diphosphate; adenosine also required. [13] Usually required.

177. ORGANIC COMPLEXES REQUIREMENTS: FUNGI

Data are applicable to organic complexes (vitamins) which must be supplied to each organism in its substrate. In each case, the organism synthesizes all other vitamins needed in its metabolism. Different isolates of the same species may have different requirements.

B = biotin; I = inositol; N = nicotinic acid; Pn = pantothenic acid; Pa = para-aminobenzoic acid; Px = pyridoxine; T = thiamine; O = none.

Species	Vitamins Required	Species	Vitamins Required	Species	Vitamins Required	Species	Vitamins Required
1 Absidia spp ¹	O	63 Dematium chodati & pullulans	O	24 Mortierella spp ⁶	O	188 Saccharomyces chodati	B, Pn, Px
2 A. ramosa	T ²	64 D. nigrum	T ²	25 Mucor spp ²⁷	O	189 Saccharomycodes ludwigii	B, I, N, Pn, Px, T
3 Achlya conspicua	O	65 Dendrophoma obscurans	T	26 M. mucedo	T	190 S. oviformis	B, Pn, Px
4 Allescheria boydii	B	66 Dermatea balsamea	T	27 Mycodermella lipolytica	T	191 S. tubiformis	B, Pn
5 Allomyces arbusculus	T ³	67 Diaporthe strumella	O	28 M. valida	B	192 S. uvarum	B, I
6 Alternaria solani	O	68 Diplodia macrospora	B	29 Mycosphaerella confusa	O	193 Saprolegnia delica & mixta	O
7 Amanita pantherina	T ⁴	69 Dipodascus uninucleatus	B, T	30 M. grossulariae	O	194 Schizosphaerium commune	T ²
8 Aphanomyces camptostylus	O	70 Dothidella quercus	O	31 M. sentina	T	195 Schizosaccharomyces pombe	B, I, N, Pn
9 A. phycophilus	T	71 Endothia parasitica	B, T	32 Mycotulula lactis	N	196 Schwannomyces occidentalis	B
10 Armillaria mellea	O	72 Entyloma arnosseridis	O	33 Nectria coccinea	T ¹⁷	197 Sclerotinia camelliae	B, I, T
11 Ascobolus spp ⁵	O	73 Epichloë typhina	I ¹⁷ , T	34 Nematosporea coryli	O	198 S. minor	B ¹⁷ , T ¹⁷
12 Ascochyta pisi	O	74 Epidermophyton floccosum	O	35 N. gossypii	B, I, T	199 S. sclerotiorum	T ²
13 Ascoidea rubescens	Px, T	75 Eremascus fertilis	O	36 Neocosmospora vasinfecta	O	200 Sclerotium delphinii	O
14 Ashbya gossypii	B, I, T	76 Eremothecium ashbyi	B, I, T	37 Neurospora spp ²⁸	B	201 Septoria spp ³⁵	T ²
15 Aspergillus spp ⁶	O	77 Exobasidium vaccinii	T	38 Nyctalis asterophora	T	202 S. apii	T ²
16 Basidiobolus ranarum	O	78 Flammula carbonaria & penetrans	T	39 Ophiobolus graminis	B, T	203 Sistotrema confluens	B
17 Blakeslea trispora	T ²	79 Fomes spp ¹⁸	T	40 O. miyabeanus	O	204 Sordaria fimicola	T
18 Blastocladiella pringsheimii	B, N, T	80 F. fraxineus	O	41 O. oryzae	B	205 Spathularia flavidia	B, Px, T
19 Blastomyces brasiliensis	T	81 Fusarium spp ¹⁹	O	42 O. caeruleum	T	206 Spermophthora gossypii	O
20 B. dermatitidis	O	82 F. avenaceum ²⁰	B	43 O. fagi	B ¹⁷ , Px	207 Sphaerobolus stellatus	O
21 Boletus spp ⁷	T	83 Ganoderma lucidum	T	44 Panaeolus campanulatus	T	208 Sphaeropsis malorum	O
22 Botrytis allii & cinerea	O	84 Glenospora loboii	O	45 Panus stipticus & torulosus	T	209 Sphaerulina trifolii	T
23 Brettanomyces bruxellensis	Px	85 Gloeocladium fimbriatum	O	46 Parasitella simplex	T	210 Sporotrichum spp ³⁶	O
24 Bulgaria inquinans	T	86 Gloeocystidium roseo-cremum	T	47 Penicillium spp ²⁹	O	211 S. schenckii	T
25 Calocera viscosa	T	87 Glomerella cingulata	O	48 Penicillium spp ³⁰	T	212 Stachybotrys atra	B
26 Candida chevalieri	O	88 Grossmannia serpens	B	49 Phacidium infestans	T ¹⁷	213 Stereum frustulosum	T ³⁷
27 C. pseudotropicalis	B, N, Pn, T	89 Gymnoascus setosus	O	50 Phialophora spp ³¹	T	214 Stromatinia smilacinae	T ¹⁷
28 Cephalosporium recifei	O	90 Hansenula anomala	O	51 Pholiota adiposa	T ¹⁷	215 Syncephalastrum cinereum	O
29 Ceratostomella spp ⁸	B, Px, T	91 Haplosporangium parvum	O	52 P. mutabilis & squarrosa	T	216 Thamnium elegans	O
30 Ceratostomella spp ⁹	Px, T	92 Helminthosporium spp ²¹	O	53 Phoma apicola & betae	O	217 Thielaviopsis basicola	T
31 C. adiposum	I	93 Helvella infula	T	54 Phycomyces blakesleeanus	T	218 Telletia horrida	T ⁴
32 C. rostricylindrica	O	94 Hemispora stellata	T	55 P. nitens	T	219 T. levis	O
33 C. stenoceras	T	95 Histoplasma capsulatum	O	56 Phymatotrachelum omnivorum	O	220 T. tritici	T
34 Cercospora appi & beticola	O	96 Hormiscium dermatitidis	T	57 Phytophthora spp ⁶	T	221 Torulaspora delbrückii	B
35 Chaetocladium brefeldii	T	97 Hormodendrum algeriensis	O	58 Pichia alcoholophila	B	222 T. fermentati	B
36 Chaetomium spp ¹⁰	B, T	98 H. langeroni	T	59 P. belgica	B, I, Px, T	223 Torulopsis candida	B
37 C. convolutum	O	99 Hydnum spp ²²	T	60 P. dombrowski	T	224 T. dattila	B, Px, T
38 Chaetostylum fresenii	O	100 H. coraloides	O	61 P. kluyveri	B, T	225 T. kefyri	N
39 Chalaropsis thielavioides	T	101 Hypophloeum fasciculare	T	62 Piedra hortae	T	226 T. laurentii & neoformans	T
40 Choanephora cucurbitarum	T	102 Hypoxylon pruinae	B, T	63 Piptopeziza freseniana	O	227 Trametes spp ³⁸	T
41 Circinella aspera & spinosa	O	103 Kloeckera brevis	B, I, N, Pn, Px, T	64 Piricularia oryzae	B, T	228 Tricholoma spp ³⁹	T
42 Cladostomium herbarum & werneckii	O	104 Lachnum pygmaeum	B, T	65 Pityrosporum ovale	B, T	229 Trichophyton spp ⁴⁰	O
43 Clavaria ligula	T	105 Lactarius deliciosus	T	66 Pleurotus curvicolle	B, T	230 Trichophyton spp ⁴¹	T
44 Clitocybe spp ¹¹	T	106 Lambertella spp ²³	B ¹⁷ , T	67 Pleurotus corticatus	T ²	231 T. faviforme	I, T
45 Clitopilus prunulus	T ⁴	107 Lentinus omphalodes	T	68 Polyporus spraguei	O	232 Trichosporon beigeli	B, T
46 Coemansia interrupta	B, T	108 Lenizites spp ²⁴	T	69 Polystictus versicolor	T	233 T. minor	T
47 Colletotrichum circinans	O	109 Lepiota amiantina & procera	T	70 Psalliotia bispora	B or T	234 Tubaria furfuracea	T
48 C. lindemuthianum ¹²	O	110 Lophodermium pinastri	B, I, T	71 P. campestris	O	235 Typhula variabilis	T
49 Collybia spp ¹³	T	111 Madurella americana	O	72 Pseudopeziza ribis	B	236 Ustilago spp ⁴²	T
50 C. dryophila	B, T	112 Malassezia furfur	T	73 Pyrenopeziza confluens	T	237 Ustilago spp ⁴³	O
51 Coprinus spp ⁶	T	113 Marasmius spp ²⁵	T	74 P. domesticum	O	238 Ustilula vulgaris	O
52 Cordyceps militaris	O	114 M. perforans	B, T	75 Pythiomorpha oryzae	T	239 Valsa ceratophora	T
53 Coryne sarcoides	B, T	115 Melanconium betulinum	B, I, T	76 Pythium spp ³²	O	240 V. pini	B, I, T
54 Cudonia circinans	T	116 Melanospora destruens	B, T	77 Pythium spp ³³	T	241 Venturia inaequalis	O
55 Cunninghamella spp ¹⁴	O	117 Memnoniella echinata	B	78 Rhizopogon roseolus	B ¹⁷ , T	242 Xylaria arbuscula	O
56 Cyathospora striatus	T	118 Merulius lachrymans	T	79 Rhizopus spp ⁶	O	243 X. hypoxylon	T
57 Dacryomyces stillatus	T	119 Microsporum spp ²⁶	O	80 Rhodotulula spp ³⁴	T ²	244 Zygorhynchus spp ⁴⁴	O
58 Daedalea spp ¹⁵	T	120 M. audouinii	N, Px ¹⁷	81 R. aurantiaca	Pa	245 Zygosaccharomyces spp ⁴⁵	B, T
59 Daldinia concentrica	O	121 Monascus purpurea	O	82 R. aurea & glutinis	O	246 Z. lactis & marxianus	B, N
60 Dasyscypha immersus	T	122 Monilia fructicola	O	83 Rosellinia arcuata	B	247 Z. nadsonii & pastori	B, Pn
61 Debaryomyces spp ¹⁶	B	123 M. laxa	T ¹⁷	84 R. necatrix & thelena	O	248 Z. japonicus	B, I, Pn, T
62 D. membranefaciens	B, T			85 Saccharomyces carlsbergensis	Px	249 Z. pini	B
						250 Z. priorianus	B, I, Pn

/1/ Spp: caerulea, glauca, orchidis, repens, spinosa. /2/ Required only pyrimidine portion of molecule. /3/ Plus an unknown "cofactor" which is neither nicotinic acid nor biotin. /4/ Can be replaced by pyrimidine + thiazole. /5/ Spp: denudatus, furfuraceus, leveillei. /6/ All species tested. /7/ Spp: elegans, granulatus, luteus, piperatus, variegatus, viscidus. /8/ Spp: fimbriata (2 isolates require thiamine only), ips, microspora, montium, penicillata, piceaperda, pini. /9/ Spp: multiannulata, pluriannulata, pilifera, pseudotsugae (partial requirement for thiamine). /10/ Spp: bostrychodes, cochlioides, elatum, globosum. /11/ Spp: alexandri, aurantiaca, clavipes, cyathiformis, geotropa, infundibuliformis, nebularis, odora, pithyophila. /12/ Certain isolates; certain other isolates have a partial requirement for inositol. /13/ Spp: ambusta, butyracea, tuberosa (cf Fn 2). /14/ Spp: bertholletiae, echinulata, elegans. /15/ Spp: confragosa, quercina, unicolor. /16/ Spp: fabrii, guillermondi, hudeloi, matrucoti, subglobosus. /17/ Partial requirement, some synthesis of the vitamin presumably takes place. /18/ Spp: annosus, igniarius, pinicola. /19/ Most species tested. /20/ One strain only. /21/ Spp: gramineum, sativum, victoricae. /22/ Spp: auriscalpium, corrugatum, erinaceus. /23/ Spp: corni-maritima, horariae, pruni, viburni. /24/ Spp: abietina, trabea (cf Fn 17); betulina, saepiaria. /25/ Spp: alliaceus, chordalis, epiphyllus, foetidus, fulvo-bulbillosum, graminum, perforans, peronatus, putillus, ramealis, rotula, scorodoni. /26/ Spp: canis, ferrugineum, fulvum. /27/ Spp: circinelloides, genevensis, griseolilacinus, himialis, mucilaginosus, stolonifer, tenuis. /28/ Spp: crassa, sitophila, tetrasperma. /29/ All other species tested. /30/ Spp: candida, fraxinea, junipericola, septentrionalis, violaceo-livida. /31/ Spp: compactum, jeanselmei, pedrosoi, verrucosa. /32/ Spp: debaryanum, deliense, graminicolum, hyphalostictum, intermedium, irregulare, mamillatum, scleroteichum, splendens. /33/ Spp: ascothallum, polymostum, arhenomanes (cf Fn 37); butleri, oligandrum, polycladon (cf Fn 2). /34/ Spp: aurantiaca, flava, mucilaginosus, rubra, sonneri (cf Fn 2). /35/ Spp: azaleae, callistephi, chrysanthemella, nodorum. /36/ Spp: beurnmanni, councilmanni, gougeroti. /37/ Requires only thiazole portion of molecule. /38/ Spp: cinnabarinaria, heteromorpha, serialis. /39/ Spp: albobrunneum, flavobrunneum, imbricatum, nudum, personatum, pessundatum. /40/ Spp: rubrum, sabouraudi, tonsurans. /41/ Spp: interdigitale, rosaceum, sulfureum, violaceum. /42/ Spp: pinguiculae, scabriosae, vinosa, violacea. /43/ Spp: avenae, bromivora, hordel, levis, nuda, striiformis, tritici, zeae. /44/ Spp: dangeardi, exponens, heterogamus, scabrieri. /45/ Spp: bisporus, mandshuricus.

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1/ Sugar commonly used for taxonomic differentiation of yeast species. 2/ All yeasts listed assimilate ammonium sulfate. 3/ *Candida melibiosi* var. *membranaefaciens*. 4/ *Candida krusoides*. 5/ *Candida chodati*. 6/ *Candida guilliermondii*. 7/ *Candida guilliermondii* var. *membranaefaciens*. 8/ *C. chalmersi*. 9/ *Zygosaccharomyces lactis*. 10/ *Zygosaccharomyces pastori*. 11/ *Torulopsis caroliniana*. 12/ *Candida utilis*.

[illegible]

179. NUTRIENTS: CHEMICAL ELEMENTS (SUMMARY)

If an organism cannot achieve typical growth, health, or reproduction in the absence of an element, the element is listed as R (or r). If addition of an element not required improves growth, health or reproduction, the element is listed as s. Accumulation in the tissues of an organism is not, alone, taken as sufficient evidence of requirement. Characterizations are subject to change with further study and increasing purity of materials.

R = Required by all forms studied; R̄ = Not required by any forms studied; r = Required by one or more species or strains; "u" = Utilized as effectively, replaces wholly or is interchangeable with another element for one or more species or strains; u< = Can partially replace or spare another element for one or more species or strains; s = Stimulates growth or other processes for one or more species or strains; a = Accumulated in the tissue of one or more forms; c = Commonly present in the food of some forms and in the tissues at similar concentrations but requirement is uncertain.

Nutrient	Higher Green Plants ¹	Fungi	Yeasts	Bacteria	Algae	Green Phyto-flagellates ²	Protozoa ³	Invertebrates		Vertebrates
								Insects	Other	
1 Aluminum	r, s, a	R̄	R̄	R̄, u< ⁴	R̄	R̄	R̄	R̄		R̄
2 Arsenic	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	a	R̄
3 Boron	R̄	R̄, s	R̄	r	r	r?	R̄	R̄	R̄	R̄
4 Bromine	R̄	R̄	R̄	R̄	R̄, a	R̄	R̄	R̄	r? ⁵ , a?	R̄
5 Calcium	R̄	r, s, a	r, u= ⁶	r, s	R̄	R̄	R̄	r, c	R̄	R̄
6 Carbon	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄
7 Chlorine	r, s	R̄	R̄	R̄	a	R̄	R̄	r, c	R̄	R̄
8 Chromium	R̄	R̄	R̄	u= ⁷	R̄	R̄	R̄	R̄	R̄	R̄
9 Cobalt	r	r	u= ⁶	r	r	r	r	r? ⁸ , s?	R̄	R̄
10 Copper	R̄	R̄	R̄	r, u< ⁴	R̄	R̄	R̄	r, c	R̄	R̄
11 Fluorine	R̄, a	R̄	R̄	R̄	R̄	R̄	R̄	R̄	a	R̄, s
12 Gallium	R̄	R̄, s	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄
13 Hydrogen	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄
14 Iodine	R̄, s	R̄	R̄, s	R̄, s	R̄, a	R̄	R̄	R̄	r? ⁹ , a	R̄
15 Iron	R̄	R̄	R̄	r, u< ⁴	R̄	R̄	R̄	R̄	R̄	R̄
16 Magnesium	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄
17 Manganese	R̄	r, s	r, u= ⁶	r, u=	r	r	r	r, c, a	r ⁸	R̄
18 Molybdenum	R̄, a	R̄ ⁹ , s	r	r ⁹	r ⁹	R̄	R̄	R̄	R̄	R̄ ¹⁰
19 Nitrogen	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄
20 Oxygen	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄
21 Phosphorus	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄
22 Potassium	R̄	R̄	r	r	R̄, a	R̄	R̄	r, c, a	R̄	R̄
23 Rubidium	R̄	R̄	R̄	u= ¹¹	R̄	R̄	R̄	R̄	R̄	R̄
24 Selenium	R̄, a	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄
25 Silicon	r	R̄	R̄	R̄	R̄	R̄	R̄	R̄	r	R̄
26 Sodium	r? ¹² , s, a	R̄	R̄	r	R̄, a	R̄	r	r? ¹³ , c	R̄	R̄
27 Strontium	R̄	R̄	R̄	u= ¹²	R̄, u=	R̄	R̄	R̄	R̄	R̄
28 Sulfur	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄
29 Tungsten	R̄	s	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄
30 Vanadium	R̄	R̄, s	R̄	u< ¹³	r	R̄	R̄, s?	R̄	r ¹⁴	R̄
31 Zinc	R̄	R̄	R̄	r, u=	R̄	R̄	R̄	R̄	r? ¹⁵ , a	R̄

/1/ Spermatophytes (the intact plant). /2/ = Green phytoflagellates, chrysomonads, dinoflagellates. /3/ Including the colorless phytoflagellates. /4/ u< = Mn or Cr for *Aerobacter aerogenes*. /5/ Occurs in scleroprotein of certain corals as di-bromotyrosine. /6/ "u=" = Ca in yeast co-carboxylase. /7/ "u" = Mn for *Aerobacter aerogenes*. /8/ In blood respiratory pigment of *Pinna squamosa* (mollusk). /9/ R for NO₃⁻ utilization by some fungi and some algae; R for N₂ fixation by some bacteria and algae. /10/ "Xanthine oxidase factor." /11/ "u=" = Ca by some. /12/ "u=" = Ca by *Azotobacter*. /13/ u< = Mo in N₂ fixation. /14/ In blood pigment of certain tunicates (Chordata).

180. NUTRIENTS: GENERAL NITROGEN SOURCES (SUMMARY)

R = Required by all forms studied; R̄ = Not required by any forms studied; r = Required by one or more species or strains; rm = Required by one or more mutants; U = Utilized by all forms studied; Ū = Not utilized by any forms studied; u = Utilized by one or more species or strains; * = Not utilized by one or more species or strains; s = Stimulates growth or other processes for one or more species or strains; * = Serves as adequate or partial N-source for one or more species or strains; ** = Simplest adequate N-source for one or more species or strains.

Nutrient	Higher Green Plants	Fungi	Yeasts	Bacteria	Algae	Green Phyto- flagellates	Protozoa	Invertebrates		Vertebrates
								Insects	Other	
Inorganic Nitrogen Sources										
1 Nitrogen, molecular, N ₂	u ¹	R̄, u? ²	R̄, u* ³	R̄, u* ³	R̄, u* ³	R̄, u* ³	R̄, u* ³	R̄, u* ³	R̄, u* ³	R̄, u* ³
2 Ammonia, -ium, NH ₃ , -NH ₄ ⁺	R̄, U**	rm, u* ⁵	R̄, u* ⁵	R̄, u* ⁵	R̄, u* ⁵	R̄, U**	r, u* ⁶	R̄, u?		R̄, u? ⁷
3 Hyponitrite, HN ₂ O ₂ ⁻ or -N ₂ O ₂ ⁻	R̄, u ⁸	R̄, u	R̄, u	R̄, u ⁹	R̄, u	R̄	R̄	R̄		R̄
4 Nitrite, -NO ₂ ⁻	R̄, u* ¹⁰	rm, u* ¹¹	R̄, u*	R̄, u*	R̄, u* ¹²	R̄	R̄	R̄		R̄
5 Nitrate, -NO ₃ ⁻	R̄, U*	rm, u* ¹³	R̄, u* ¹⁴	R̄, u* ¹⁵	R̄, U*	R̄, u*	R̄, u	R̄		R̄
6 Nitrohydroxamate, -HN ₂ O ₃ ⁻	R̄, u* ¹⁶	R̄, u* ¹⁷	R̄	R̄	R̄	R̄	R̄	R̄		R̄
7 Cyanide, -CN ⁻	Ū	R̄, u* ¹⁸	R̄	R̄	R̄	R̄	Ū ¹⁹	Ū ¹⁹		Ū ¹⁹
8 Thiocyanate, -CNS ⁻	Ū	R̄, u?	R̄, u	R̄, u*	R̄	R̄	Ū	Ū		Ū
9 Cyanamide, -NHCN ⁻	Ū	u* ²⁰	R̄	R̄, u* ²⁰	R̄	R̄	Ū	Ū		Ū
Organic Nitrogen Sources										
10 Oximino compounds, RONH ₂	R̄, Ū ²¹	R̄, u*	R̄, u?	R̄, u* ²²	Ū ²³	R̄	R̄	R̄		R̄
11 Amines, RNH ₂	R̄	R̄, u*	R̄, u*	R̄, u*	R̄, u* ²⁴	R̄	R̄	R̄		R̄
12 Acid imides, (RCO) ₂ NH	R̄	R̄	R̄	R̄, u*	R̄	R̄	R̄	R̄		R̄
13 Acid amides, RCONH ₂	R̄, u* ²⁵	R̄, u* ²⁶	r, u*	R̄, u*	R̄, u*	R̄	R̄	R̄		R̄
14 Urea, (NH ₂) ₂ CO	R̄, U*	R̄, u*	R̄, u*	R̄, u*	R̄, u*	R̄, u*	R̄, u* ²⁷	R̄		R̄, u* ²⁸
15 Amino acids, RCH(NH ₂)COOH	R̄, u*	r, rm, U*	r, U*	r, U*, s	R̄, u* ²⁹	r, u*	r, u*	R̄, U**	R̄, U**	R̄, U* ⁷
16 Peptides, polypeptides	R̄, u*	R̄, u*	R̄, u*	r, u*, s	R̄, u*	R̄, u*	r, u*	R̄		R̄, U*
17 Proteins	R̄	R̄, u*	R̄, u*	R̄, u*	R̄	R̄	r, u*	R̄, U*	U*	R̄, U*, s
18 Imidazole compounds	R̄	R̄, u*	R̄, u*	R̄, u*	R̄	R̄	R̄	R̄		R̄
19 Pyridine compounds	R̄	R̄	r	r, u*	R̄	R̄	r	r		r
20 Pyrimidine compounds	R̄	R̄, u*, s	R̄, u*	R̄, u*, s	r	r	r, u*	r		r
21 Purine compounds	R̄, u	rm, u*, s	R̄, u	R̄, u*, s	R̄	R̄	r, u*	R̄		R̄
22 Indole compounds	R̄, s	rm, u*	R̄	R̄, u*, s	R̄, s	R̄, s	R̄	R̄		R̄

/1/ U by virtue of symbiotic bacteria as in root nodules or legumes. /2/ Evidence for N₂ fixation conflicting. /3/ U by N₂ fixing bacteria. /4/ N₂ "fixation" by blue-green algae, Nostocaceae. U if H₂ or CO present. /5/ U by *Phycomyces blakesleeana*, Mucorales. Probably U by all fungi. /6/ U in preference to NO₃⁻ by *Chlorella*. /7/ Dietary NH₄⁺ U by ruminants; possibly others; NH₄⁺ originating as metabolic intermediate U in amino acid synthesis. /8/ U by tobacco plant. /9/ U by *Clostridium pasteurianum*, but not for growth; U for denitrification by *Pseudomonas stutzeri*. /10/ Toxic to many plants, poorly U by tobacco plant. /11/ U as sole N-source by many fungi. /12/ U poorly by *Chlorella pyrenoidosa*. /13/ Acts as sole H acceptor in anaerobic metabolism of *Aspergillus niger*. R by some when mannitol is carbon source. Some R NO₃⁻, cannot substitute NH₄⁺. /14/ U poorly by most yeasts. /15/ U by purple photosynthetic bacteria. /16/ Good N-source for tobacco plant. /17/ Good N-source for *Aspergillus niger*. /18/ U by *Aspergillus niger* when N-starved. /19/ Toxic. /20/ Cyanamide and derivatives U by many. /21/ Hydroxylamine poor N-source. /22/ Hydroxylamine U by *Clostridium welchii*, U in non-toxic concentration by *Nitrosomonas*. /23/ Hydroxylamine toxic. /24/ Glucosamine U. /25/ Acetamide U by some. /26/ Formamide and others U by *Aspergillus*. Both amino and amide N of asparagine U by *Aspergillus*. /27/ U by *Astasia longica* (colorless phytoflagellate). /28/ U by ruminants via rumen microflora. /29/ L-arginine, glutamine, cysteine, L-asparagine support more rapid growth of *Chlorella* than does NH₄⁺.

181. NUTRIENTS: AMINO ACIDS, PEPTIDES, PROTEINS (SUMMARY)

R = Required by all forms studied; R̄ = Not required by any form studied; r = Required by one or more species or strains; rm = Required by one or more mutants; U = Utilized as a source of nitrogen and/or carbon by all forms studied although not a specific requirement for all; u = Utilized by one or more species or strains as a source of nitrogen and/or carbon although not a specific requirement; "u=" = Replaces effectively one or more other amino-acids, one of the interchangeable series being required in the diet; ð = Not utilized by one or more species or strains; s = Stimulates growth or other processes for one or more species or strains; * = Serves as complete nitrogen source for one or more species or strains; ** = Serves as simplest complete nitrogen source for one or more species or strains.

Nutrient	Higher Green Plants ¹	Fungi	Yeasts	Bacteria	Algae	Green Phyto-flagellates ²	Invertebrates		Vertebrates
							Protozoa ³	Insects	
1 Organic N (per se)	R̄, u*	r, rm, u*	r, rm, u*	r, u*	R̄, u*	r, u*	r, U*	R, U*	R, U*
2 Proteins (per se)	R̄	R̄, u*	R̄, u*	R̄, u*	R̄	u	r ⁵ , u*	R̄ ⁶ , s, U*	R̄ ⁶ , s, U*
3 Polypeptides ⁷ , peptones	R̄, u*	R̄, u*	R̄, u*	r, u*	R̄, u*	u=9, u*	r, u*	R̄, U	R̄, U
4 Amino acids	R̄, u* ¹⁰	r, rm, u*	rm, u* ¹¹	r ¹² , rm, u*	R̄, u* ¹³	r, u=9, u* ¹⁴	r ¹⁵ , u*	R̄, U**	R̄, U**
5 Alanine	R̄, u*	u*, u=16	u*	r, u*	R̄, u*	R̄, u*	u	r ¹⁷ , u=	R̄, U
6 Arginine	R̄, u*	rm, u*	rm, u*	r, rm, u*	R̄, u*	R̄, u*	r ¹⁸ , s, u	r ¹⁷	r ¹⁹ , U
7 Aspartic acid ²⁰	R̄, u*	u*, u=16	u*	r, u*	R̄, u*	r, u*	u, s	r ¹⁷ , u=	R̄, U
8 Citrulline	R̄	rm, u*	u*	r, u*	R̄, u*		u	r, u=21	R̄, u=21, U
9 Cysteine	R̄, u*	rm, u*	u*	r, u*	R̄, u*		u	r, u=	R̄, U
10 Cystine	R̄, u*	rm, u*	u*	r, rm, u*	R̄		u	r ¹⁷ , u=	R̄, U
11 Glutamic acid ²⁰	R̄, u*	rm, u=16, u*	u*	r, u*	R̄, u*	R̄, u*	u, s	r ¹⁷ , u=	r ²² , U
12 Glycine	R̄, u*	rm, u*	u*	r, u*	R̄, u*	R̄, u*	r ¹⁸ , u	r	r ²³ , U
13 Histidine	R̄, u*	r, rm, u*	r, u*	r, rm, u*	R̄, u*	R̄, u*	r ¹⁸ , s, u	r ¹⁷	r ²⁴
14 Isoleucine	R̄, u*	rm, u*	rm, u*	r, rm, u*	R̄, u*	R̄, u*	r ¹⁸ , u	r ¹⁷	R ²⁴
15 Leucine	R̄, u*	rm, u*	rm, u*	r, rm, u*	R̄, ð	R̄, u*	r ¹⁸ , u	r ¹⁷ , u=	R ²⁴
16 Lysine	R̄, u*	rm, u*	u*	r, rm, u*	R̄, ð	R̄, u*	r ¹⁸ , u	r ¹⁷	R ²⁴
17 Methionine	R̄, u	r, rm, u*	r, u*	r, rm, u*	R̄, ð	r	r ¹⁸ , u	r ¹⁷ , u=	R ²⁴ , 25
18 Phenylalanine	R̄, u*	rm, u*	rm, u*	r, rm, u*	R̄, ð	R̄, u*	r ¹⁸ , u	r ¹⁷ , u=	R ²⁴ , 25
19 Proline	R̄, u*	rm, u*	u*	r, u*	R̄, ð	R̄, u*	r ¹⁸ , u	r ¹⁷	r, U
20 Serine	R̄, u*	rm, u*	u*	r, u*	R̄, ð	R̄, u*	r ¹⁸ , s, u	r ¹⁷	R̄, U
21 Threonine	R̄, u*	rm, u*	u*	r, u*	R̄, ð	R̄, u*	r ¹⁸ , u	r ¹⁷ , u=	R ²⁴
22 Tryptophan ²⁶	R̄, u*	r, rm, u*	u*	r, rm, u*	R̄, ð	R̄, ð	r ¹⁸ , u	r ¹⁷ , s, u=	R ²⁴
23 Tyrosine	R̄, u*	rm, u*	u*	r, rm, u*	R̄, ð	R̄, ð	r ¹⁸ , u	u=	R̄, U
24 Valine	R̄, u*	rm, u*	u*	r, rm, u*	R̄, u*	R̄, u*	r ¹⁸ , s, u	r ¹⁷ , u=	R ²⁴

/1/ Spermatophytes (the intact plant). /2/ Green phytoflagellates, chrysomonads, dinoflagellates. /3/ Including colorless phytoflagellates. /4/ Most grow better on organic than on inorganic N. /5/ Many require living prey. /6/ On assumption that suitable amino acid combinations can replace complete proteins. /7/ See streptogenin (table 185). /8/ Entire peptides, polypeptides, low molecular weight proteins directly assimilated by some. /9/ Either 3 or 4 required by photoautotrophs growing in dark. /10/ Several tested intact plants grow on single amino acids as sole N-source. Growth attained on some amino acids is superior to that achieved with NH₄⁺, NO₃⁻, as N-source, on other amino acids inferior. Some plants grow less well on amino acids than on inorganic N. Marked differences exist between species with respect to amino acid utilization. Some amino acids are toxic, under the experimental conditions used, for some plants. Among plants tested are: tomato, tobacco, clover, peas, orchid embryos, young orchid. /11/ Amino acid mixtures superior to NH₄⁺ as N-source for some, e. g. *Saccharomyces cerevisiae*, *S. carlsbergensis*. /12/ Wide differences of requirement exist between species, species mutants, e. g. *Leuconostoc mesenteroides* R all the amino acids listed except 5 and 8. *Lactobacillus bifidus* R only 9. /13/ Based mainly on *Chlorella pyrenoidosa*. /14/ Marked differences between various species and varieties with respect to amino acid utilization; environmental conditions sharply modify. /15/ Best known requirement are those of *Tetrahymena*, *Trichomonas foetus*, *Herpetomonas culicidarum*, *Glaucoma scintillans*. /16/ Interchangeable for a *Neurospora* mutant. /17/ Basic common requirements of *Tribolium confusum*, *Drosophila melanogaster*, *Aedes aegypti*, *Blattella germanica* are covered by 6, 10, 13-18, 21, 22, 24. For *A. aegypti* 18 or 21 + 22 + 24 may be eliminated from diet. For *B. germanica* 5, 7, 11 u=, but one at least must be present; male also R 19, 20; 9, 10, 17 u=, and may be replaced by homocysteine, cystic acid, isethionic acid, inorganic SO₄; 15, 24 u=; 18-23 u=, and may be replaced by 3, 4-dihydroxyphenylalanine, phenylacetic, 2, 4-dihydroxybenzoic, shikimic, orsellinic acids. /18/ R by *Tetrahymena geleii*, *Glaucoma scintillans*, *Trichomonas foetus*, *Herpetomonas culicidarum* are 6, 13-18, 22, 24; in addition *G. scintillans*, *T. foetus* R 12, 19-21 and *H. culicidarum* R 23. *T. geleii* needs no other carbon source. /19/ R by rat, chicken. /20/ Asparagine (amide of 7) and glutamine (amide of 11) U by at least some in all the groups listed and R by some. /21/ 6, 8 interchangeable for some. /22/ R by chick. /23/ R by chick for rapid growth. /24/ R by man, mouse, rat, chicken. 13 not required to maintain nitrogen balance in adult human. /25/ Amount of methionine R by man depends on amount of cystine in diet. Amount of phenylalanine R by man depends on amount of tyrosine in diet. /26/ Precursor of niacin which it spares for some organisms.

182. NUTRIENTS: LIPIDS (SUMMARY)

R̄ = Not required by any form studied; r = Required by one or more species or strains; rm = Required by one or more mutants; u = Utilized by one or more species or strains; "u=" = Utilized as effectively as a related substance by one or more species or strains; s = Stimulates growth or other processes for one or more species or strains; i = Inhibits growth or other processes for one or more species or strains.

of other processes for one or more species of strains; 1 = minimum growth of other processes for one or more species of strains.										
Nutrients		Higher Green Plants ¹	Fungi	Yeasts	Bacteria	Algae	Green Phyto-flagellates ²	Invertebrates		Vertebrates
								Protozoa ³	Insects	
Steroids										
1	Cholesterol	R̄	r ⁴	u	u	R̄	R̄	r ⁵	r	R̄
2	7-Dehydrocholesterol	R̄	R̄	R̄	R̄	R̄	R̄	R̄, u=6	u=	u ⁷
3	Ergosterol acetate	R̄	R̄	R̄	R̄	R̄	R̄	R̄, u=6	u=	s ⁸
4	Ergosterol	R̄	R̄	u, s	R̄	R̄	R̄	R̄, u=6	u=	u ⁹
5	Stigmasterol	R̄	R̄	R̄	R̄	R̄	R̄	R̄	u=	R̄, s
Long Chain Fatty Acids and Their Derivatives										
6	Arachidonic acid ¹⁰	R̄		R̄		R̄	R̄		s	r, u=
7	Linoleic acid ¹⁰	R̄	rm	R̄	s, i	R̄	R̄	u=11	r	r, u=
8	Linolenic acid ¹⁰	R̄		R̄		R̄	R̄		u=	r, u=
9	Oleic acid	R̄	rm, s	R̄	s, i	R̄	R̄	s, i	r	R̄
10	"Tween 80, 85" ¹²	R̄	R̄	R̄	R̄, s, i	R̄	R̄	R̄, s	R̄	R̄
11	"Myrj G 2144" ¹²	R̄	R̄	R̄	R̄	R̄	R̄	R̄, s	R̄	R̄
Phospholipids										
12	Lecithin	R̄	R̄	R̄	R̄	R̄	R̄	s	u=, s	R̄

/1/ Spermatophytes (the intact plant). /2/ Green phytoflagellates, chrysomonads, dinoflagellates. /3/ Including the colorless phytoflagellates. /4/ r by *Labyrinthula vitellina* (var. *pacifica* only). /5/ For several individual insect species various steroids u=. /6/ u= in place of 1 by *Trichomonas*. /7/ Precursor of vitamin D₃. /8/ Relieves "stiffness syndrome" of guinea pig. /9/ Precursor of vitamin D₄. /10/ The "essential fatty acids" of vertebrates. /11/ u = a required ether soluble factor of blood serum by *Trichomonas*. /12/ Synthetic detergents; "Tweens" = sorbitan esters of fatty acids, e. g. oleic; "Myrj G 2144" = polyoxalkalene derivative of oleic acid.

183. NUTRIENTS: VITAMINS AND RELATED COMPOUNDS (SUMMARY)

R = Required by all forms studied; R̄ = Not required by any form studied; r = Required by one or more species or strains; rm = Required by one or more mutants; u = Utilized by one or more species or strains; "u" = Utilized as effectively as the related compound(s) or vitamin by one or more species or strains; u> = Utilized more effectively than the related compound(s) or vitamin and considered to be required by one or more species or strains; u< = Utilized less effectively than the related vitamin by one or more species or strains; u< = Utilized as well or less effectively than the related vitamin by one or more species or strains; ≠ = Not utilized in place of the related vitamin by one or more species or strains; s = Stimulates growth or other processes for one or more species or strains; i = Inhibits growth or other processes for one or more species or strains.

Compound	Related Compound ²	Higher Green Plants ³	Fungi	Yeasts	Bacteria	Algae	Green Phytoflagellates ⁴	Invertebrates		Vertebrates
								Protozoa ⁵	Insects	
1 Vitamin A	(inc)A ₁ , A ₂ , A ₃ , (rel) 21A	R, s	R̄, s	R̄	R̄	R̄	R̄	r?	R̄	R
2 Ascorbic acid		R̄, s	R̄, s	R̄, s	R̄, s	r?, s	R̄	r, s	R̄	r
3 Biotin	(rel)20A, 24A, 30A, 34A	R̄	r, rm, s	r, s	r	r	R̄	r, s	r	r
4 Choline group ⁶		R̄, s	r, rm	R̄	r	R̄	R̄	R̄	r?	r
5 Cobalamin ⁷	(rel)39A, 45A	R̄, s	R̄	R̄	r ⁸	r	R̄	r	r?, s	R ⁹
6 Vitamin D ⁹	(inc)D ₂ , D ₃ , D ₄ etc.	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R
7 Vitamin E	(inc)α, β, γ, σ-Tocopherols	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄, s	r
8 Inositol ¹⁰	= meso-Inositol	R̄, s	r, rm, s	r, s	r?, s	R̄	R̄	R̄	r	r
9 Vitamin K	= K ₁ , K ₂	R̄	R̄	R̄	r	R̄	R̄	R̄	r	r
10 Nicotinic acid	(rel)11A, 25A, 48A	R̄, s?	r, rm, s	r	r, s	R̄	R̄	r	r	r
11 Nicotinamide	(rel)10A	R̄, s?	r, rm, s	u	r, u, s	R̄	R̄	u	u	u
12 Pantothenic acid	(rel)19A, 22A, 31A, 35A	R̄, s	r, rm, s	r	r, s	r	R̄	r	r	R?
13 Pteroylglutamic acid ¹¹	(rel)27A, 40A, 44A, 49A	R̄	R̄	R̄	r ¹²	R̄	R̄	r	r	R
14 Pyridoxal ¹³	(rel)15A, 16A, 41A, 42A	R̄	u	u, s	r, u>	R̄	R̄	u	u	u
15 Pyridoxamine ¹³	(rel)14A, 16A, 41A, 42A	R̄	u	u, s	r, u>	R̄	R̄	u	u	u
16 Pyridoxine ¹³	(rel)14A, 15A, 41A, 42A	R̄, s	r, rm, s	r, s	r, s	R̄, s	R̄	r	r	R
17 Riboflavin		R̄	rm	rm	r, s	R̄	R̄	r	r	R
18 Thiamine	(rel)26A, 32A; (co)43A+47A	R̄, s	r, rm, s, i ¹⁴	r, i ¹⁵	r, s	r	R̄	r	r	R
19 β-Alanine	(po)12A	R̄	rm, u	R̄, u	R̄, u	R̄	R̄	R̄, u	R̄	R̄, s
20 Biocytin	(rel)3A	R̄	R̄	u	R̄	R̄	R̄	R̄	R̄	R̄
21 β-Carotene ^{16, 17}	(pre)1A	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄, u<
22 Coenzyme A	(co)12A+ADP+PO ₄	R̄	R̄	R̄, s	r, u>	R̄	R̄	R̄	R̄	R̄, u<
23 5, 6-Dimethylbenzimidazole	(po)5A	R̄	R̄	R̄	R̄	R̄	R̄, u<	R̄	R̄	R̄, u<
24 Desthiobiotin	(rel)3A, 30A, 34A	R̄	R̄	R̄	R̄, u<	R̄	R̄	R̄	R̄	R̄
25 DPN ¹⁸	(co)10A+ribose PO ₄	R̄	r, u>, s	R̄, u	r, u	R̄	R̄	R̄	R̄, u<	R̄, u<
26 Diphosphothiamine	(co)18A+PO ₄	R̄	R̄, u<	R̄, u	r, u>	R̄	R̄, u	R̄, u	R̄	R̄, u
27 Folic acid conjugates ¹⁹	(co)13A+glutamate	R̄	R̄	R̄	R̄, u	R̄	R̄	R̄, u	R̄, u	R̄, u
28 Folinic acid ²⁰	(rel)13A	R̄	R̄	R̄	r	R̄	R̄, u	R̄, u	R̄	R̄, u<
29 Hesperidin ²¹	(po)"Vitamin P" series	R̄, s	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄, s
30 O-Heterobiotin	(rel)3A, 24A, 34A	R̄	R̄	R̄	R̄, u<, u	R̄	R̄	R̄	R̄	R̄
31 L. B. factor ²²	(rel)12A	R̄	R̄	R̄	r, u>	R̄	R̄	R̄	R̄	R̄
32 Lipothiamide	(co)18A+lipoic acid	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄, u
33 Lyxoflavin	(rel)17A	R̄	R̄	R̄	R̄, u<	R̄	R̄	R̄	R̄	R̄, s, u<
34 Oxybiotin	(rel)3A, 24A, 30A	R̄	R̄	R̄	R̄, u<	R̄	R̄	R̄	R̄	R̄
35 "Pantothenic acid conjugate"	(co)12A+adenine+glutamate	R̄	R̄	R̄	r?, u>	R̄	R̄	R̄	R̄	R̄
36 Pantoic acid	(po)12A	R̄	R̄	R̄, u	R̄, u	R̄	R̄	R̄	R̄	R̄, u
37 Para-aminobenzoic acid	(po)40A	R̄	r, rm	r	r	R̄	R̄	R̄	R̄	R̄, s
38 Pimelic acid	(rel po)3A	R̄	R̄, s	R̄	R̄, u<	R̄	R̄, u<	R̄, u<	R̄	R̄, u
39 Pseudovitamin B ₁₂	(rel)5A	R̄	R̄	R̄	R̄, u	R̄	R̄, u	R̄	R̄	R̄, u
40 Pteric acid	(po)13A	R̄	R̄	R̄	R̄, u<	R̄	R̄, u	R̄, u	R̄	R̄, u
41 Pyridoxal-PO ₄	(rel)14A	R̄	R̄, u	R̄, u	r, u>	R̄	R̄	R̄, u	R̄, u	R̄, u
42 Pyridoxamine-PO ₄	(rel)15A	R̄	R̄, u	R̄, u	r, u>	R̄	R̄	R̄, u	R̄, u	R̄, u
43 Pyrimidine ^{23, 24}	(po)18A	R̄	r, rm, u ^{23, 24}	r, s ^{23, 24}	r, u ^{23, 24}	r ^{23, 24}	r, u ^{23, 24}	r, u ^{23, 24}	R̄	R̄, u
44 Rhizopterin	(rel po)13A	R̄	R̄	R̄	R̄, u	R̄	R̄	R̄	R̄	R̄, u
45 α-Ribazole	(po)5A	R̄	R̄	R̄	R̄	R̄	R̄, u<	R̄	R̄	R̄, s
46 Rutin ²¹	(po)"Vitamin P" series	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄	R̄, s
47 Thiazole ^{24, 25}	(po)18A	R̄	r, rm, u ^{24, 25}	r, s ^{24, 25}	r, u ^{24, 25}	r ^{24, 25}	r, u ^{24, 25}	r, u ^{24, 25}	R̄	R̄
48 TPN	(co)10A+ribose+PO ₄	R̄	r, u>, s	R̄, u	R̄, u	R̄	R̄	R̄	R̄	R̄, u
49 Xanthopterin	(rel po)13A	R̄	R̄	R̄	R̄, u<	R̄	R̄	R̄	R̄	r ²⁶ , u ²⁶ , s

/1/ Vitamin = an organic compound, other than an amino-acid, carbohydrate or essential fatty acid, required in the diet by at least one vertebrate animal. /2/ (co) = composed of; (po) = part of; (pre) = precursor of; (rel) = related to; (inc) = includes. /3/ Spermatophytes (the intact plant). /4/ Green Phytoflagellates, chrysomonads, dinoflagellates. /5/ Including the colorless phytoflagellates. /6/ Includes: choline, betaine and other methyl donors. /7/ Generic term including cyanocobalamin, hydroxocobalamin, vitamins B₁₂, B_{12a}, B_{12b}. /8/ For some, thymine desoxyriboside, hypoxanthine, adenine, guanine may substitute in certain media. /9/ D₂ active for mammals only; D₃ active for all and R by chicken. /10/ Of doubtful status as a vitamin. /11/ = Folic acid, folacin. /12/ For one or more, pteric acid (q. v. 40A) or thymine + thymidine will substitute. /13/ Member of the pyridoxine group (Vitamin B₆). /14/ Inhibits growth of *Rhizopus nigricans*. /15/ Inhibits growth of strains of *Saccharomyces cerevisiae*. /16/ And other carotenoid precursors of Vitamin A. /17/ R? by certain crustacea whose eyes contain vitamin A. /18/ Diphosphopyridine nucleotide. /19/ Di-, tri- and hepta-glutamates of pteroylglutamic acid. /20/ = The citrovorum factor, R by *Leuconostoc citrovorum*. /21/ 29, 46 and citrin = "vitamin P" series. /22/ *Lactobacillus bulgaricus* factor which = pantetheine, pantethine, (N-(pantothenyl) β-amino-ethanol and corresponding di-sulfide?). /23/ Thiamine or pyrimidine moiety, (thiazole moiety is synthesized). /24/ Thiamine or pyrimidine + thiamine moieties, (pyrimidine and thiazole moieties combined to give thiamine). /25/ Thiamine or thiazole moiety, (pyrimidine moiety is synthesized). /26/ More active than pteroylglutamic (folic) acid in relieving anemia of Chinook salmon, (fish).

184. NUTRIENTS: PURINES, PYRIMIDINES (SUMMARY)

⌘ = Not required by any form studied; r = Required by one or more species or strains; rm = Required by one or more mutants; u = Utilized by one or more species or strains; ⌘ = Not utilized by one or more species or strains; "u=" = Utilized as effectively as (or interchangeably with) one or more related compounds, the presence of at least one of the series being required by one or more species or strains. u< = Partially replaces or spares one or more required or interchangeably required compounds for one or more species or strains; s = Stimulates growth or other processes for one or more species or strains; i = Inhibits growth or other processes for one or more species or strains.

Nutrient	Higher Green Plants	Fungi	Yeasts	Bacteria	Algae	Green Phyto-flagellates	Invertebrates		Vertebrates
							Protozoa	Insects	
1 Pyrimidine compounds	⌘	r, rm, s	r, s	r, s, u	r	r	r, s	r	⌘, s
2 Purine compounds	⌘	rm, s, u	s, u	r, s, u	⌘	⌘	r, s	r	⌘, s
3 Cytidine	⌘	⌘, rm, s	⌘	u=1	⌘	⌘	u=, i	⌘	⌘
4 Cytidylic acid	⌘	⌘, rm, s ²	⌘	u=1	⌘	⌘	u=, s	⌘	⌘
5 Cytosine	⌘	rm	⌘	u=3	⌘	⌘	r?, u ⁴ , i	⌘	⌘
6 Orotic acid	⌘	rm, s ²	⌘	r ⁵ , s	⌘	⌘	⌘, u ⁴	⌘	⌘, s
7 Pyrimidine		(See table H16)							
8 Thymine	⌘	⌘	⌘	u=6, u<7	⌘	⌘, u<8	r?, u<9	r	⌘, s
9 Thymidine	⌘	⌘	⌘	u<7	⌘	⌘	u<9	⌘	⌘, s
10 Uracil	⌘	rm, s ²	⌘	u=1, s	⌘	r?	r, u=10	r ¹¹	⌘
11 Uridine	⌘	⌘, rm, s	⌘	u=1, s	⌘	⌘	u=	⌘	⌘
12 Uridylic acid	⌘	⌘, rm, s ²	⌘	u=1, s	⌘	⌘	u=	⌘	⌘
13 Adenine	⌘	rm	r ¹²	u=13	⌘	⌘, u<8	r?, u<14	r ¹¹	⌘, s
14 Adenosine	⌘	⌘	⌘	u=13	⌘	⌘	⌘, u<14	⌘	⌘
15 Adenosine triphosphate	⌘	⌘	⌘	u=13	⌘	⌘	⌘, s	⌘	⌘
16 Adenylic acid	⌘	⌘	⌘	u=13	⌘	⌘	r, u<14	⌘	⌘, s
17 Guanine	⌘	r, rm, s	⌘	u=13, s	⌘	s	r ¹⁵	r ¹¹	⌘
18 Guanidine	⌘	⌘	⌘	u=13	⌘	⌘	r?, u=, u<16, i	⌘	⌘
19 Guanidylic acid	⌘	⌘	⌘	u=13	⌘	⌘	u=, s	⌘	⌘
20 Hypoxanthine	⌘	r, rm	⌘	u=13, s	⌘	s	u=, u<14	⌘	⌘
21 Xanthine	⌘	⌘	⌘	u=12, s	⌘	⌘	r?, u<14	⌘	⌘
22 Others	⌘	⌘	⌘	⌘	⌘	⌘	s ¹⁸	⌘	⌘

/1/ At least one required, but interchangeable, for several species, e.g. Clostridium tetani, Hemophilus parainfluenzae. /2/ Stimulates mutants of Neurospora. /3/ Lactobacillus arabinosus, Leuconostoc mesenteroides r 5 or 17 (interchangeable). /4/ ⌘ by Tetrahymena. /5/ r by Lactobacillus bulgaricus 09. /6/ Clostridium tetani r either 13 or 20 (interchangeable). /7/ Spares folic acid for Streptococcus lactis; 8 + 9 replaces folic acid for S. lactis. /8/ Spares, and given with amino-acids, substitutes for para-aminobenzoic and folic acids for Euglena gracilis. /9/ Spares folic acid for Tetrahymena. /10/ For Tetrahymena, 10 or 3, 4, 11 or 12 r. /11/ Drosophila melanogaster r 10 + sucrose, 10 + 13 + 17 or nucleic acid. /12/ r by Saccharomyces octosporus on certain media. /13/ Items 13-21 variously interchangeable for different bacteria, but at least one must be present, e.g. Streptococcus hemolyticus r at least one of 13, 14, 16, 17, 18, 19, 21 (the requirement is relieved by CO₂ in high concentration); 13, 17, 20 or 21 r Streptococcus lactis; 14 r by B. megaterium for spore germination. /14/ Spares but cannot replace 17, 18, 19, for Tetrahymena. /15/ r by Tetrahymena, replaceable by 18 or 19. /16/ Spares folic acid (as does adenosine) for Herpetomonas culicidarum. /17/ In vitro studies indicate a possible requirement of 21 and also 5, 7, 10, 13, 18 by Plasmodium. /18/ Methyl purines e.g. theobromine, theophylline, caffeine s some ciliates and Suctoria.

185. NUTRIENTS: MISCELLANEOUS GROWTH FACTORS (SUMMARY)

R = Required by all forms studied; ⌘ = Not required by any forms studied; r = Required by one or more species or strains; rm = Required by one or more mutants; "u=" = Replaces effectively or utilized interchangeably with one or more other substances, but one of the interchangeable substances must be present; s = Stimulates growth or other processes for one or more species or strains; i = Inhibits growth or other processes for one or more species or strains.

Nutrient	Higher Green Plants	Fungi	Yeasts	Bacteria	Algae	Green Phyto-flagellates	Invertebrates		Vertebrates
							Protozoa	Insects	
1 Adenylthiomethylpentose	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘, s
2 Anthranilic acid	⌘	r, rm ¹	⌘	u=1	⌘	⌘	⌘	⌘	⌘, s
3 Antibiotics	⌘, s	⌘, s	⌘	r ²	⌘	⌘	⌘, s	⌘	⌘, s
4 Asparagine	⌘	⌘	⌘, s, i	r ³	⌘	⌘	⌘	⌘	⌘
5 "Bifidus" factor ⁴	⌘	⌘	⌘	r	⌘	⌘	⌘	⌘	⌘
6 Carbon dioxide	R	r ⁵ , s, i	⌘	r ⁵ , s	R	R ⁶ , s	⌘	⌘	⌘
7 Carnitine	⌘	⌘	⌘	⌘	⌘	⌘	⌘	r ⁸	⌘
8 Coprogen	⌘	r	⌘	⌘	⌘	⌘	⌘	⌘	⌘
9 N-D-Glucosylglycine ester	⌘	⌘	⌘	r	⌘	⌘	⌘	⌘	⌘
10 Glutamine	⌘	⌘, s, i	s, i	r ³ , s	⌘	⌘	⌘	⌘	⌘
11 Glutathione	⌘	⌘	⌘	r ⁹	⌘	⌘	⌘	s ¹⁰	⌘
12 Guanidine	⌘	⌘	⌘	⌘	⌘	⌘	r? ¹¹	⌘	⌘
13 Indole-3-acetic acid ¹²	r?, s	r?, s	⌘	⌘, s	⌘, s	⌘, s ¹³	⌘ ¹³ , i	⌘	⌘, s?
14 Hematin	⌘	r	⌘	r	⌘	⌘	r	r	⌘
15 Krebs cycle intermediates	⌘	r	⌘	r ¹⁵	⌘	r ¹⁴ , s	⌘, s ¹⁴	⌘	⌘
16 Mucin	⌘	⌘	⌘	r ¹⁶	⌘	⌘	⌘	⌘	⌘, s
17 Mycobactin	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘	⌘
18 Parahydroxybenzoic acid	⌘	rm	⌘	rm	⌘	⌘	⌘	⌘	⌘
19 Putrescine	⌘	rm	⌘	r, u=17	⌘	⌘	⌘	⌘	⌘
20 Quinic acid	⌘	rm	⌘	rm	⌘	⌘	⌘	u=1 ¹⁸	⌘
21 Shikimic acid	⌘	rm	⌘	rm	⌘	⌘	⌘	u=1 ¹⁸	⌘
22 Spermidine	⌘	⌘	⌘	r, u=17	⌘	⌘	⌘	⌘	⌘
23 Strepogenin	⌘	⌘, s?	⌘	r, rm, s	⌘	⌘	⌘	⌘	⌘, s?
24 Thiocetic acid	⌘	⌘	⌘	r	⌘	⌘	r ¹⁹	⌘	⌘
25 Unidentified factors		r	⌘	r	⌘	⌘	r	r	r

/1/ Substitutes for tryptophan and/or indole. /2/ R by "dependent" mutants. /3/ R as growth factor and not replaceable by aspartic or glutamic acids. /4/ α- and β-Methyl-N-acetyl-D-glucosaminide? /5/ R by some in higher than atmospheric concentrations. /6/ R although another carbon source is available, particularly in darkness. /7/ R by some colorless phytoflagellates. /8/ R by Tenebrio molitor; interchangeable with γ-amino-β-hydroxybutyric acid. /9/ R by Neisseria gonorrhoeae. /10/ Favors larval growth of Drosophila and Aedes aegypti. /11/ Possibly R by Plasmodium in vitro; ⌘ by Tetrahymena. /12/ And related auxins. /13/ s Euglena gracilis (green phytoflagellate), ineffective for Astasia (colorless counterpart of Euglena). /14/ Several utilized for growth by the "acetate" flagellates; acetate utilized by most; wide variation among species with respect to utilization or availability of individual Krebs intermediates and related compounds such as pyruvate. /15/ Corynebacterium diphtheriae. /16/ Mycobacterium johnei. /17/ Interchangeable with spermidine for some. /18/ Spares or replaces phenylalanine, tyrosine for Blattella germanica. /19/ R by Tetrahymena geleii (8 strains), T. vorax (2 strains); spared but not replaced by acetate; R? by Peranema trichophorum.

186. NUTRIENTS: GENERAL SULFUR SOURCES (SUMMARY)

A sulfur source is required by organisms in all categories listed below.

R = Required by all forms studied; \bar{R} = Not required by any forms studied; r = Required by one or more species or strains; rm = Required by one or more mutants; U = Utilized by all forms studied; \bar{U} = Not utilized by any forms studied; u = Utilized by one or more species or strains.

Nutrient		Higher Green Plants	Fungi	Yeasts	Bacteria	Algae	Green Phytoflagellates	Invertebrates		Vertebrates
								Protozoa ¹	Insects	
Inorganic Sulfur Sources										
1	Sulfur ² (elemental), S	\bar{R}, \bar{U}	u ³	u	r ⁴	\bar{R}, \bar{U}	\bar{R}	\bar{R}	\bar{R}	\bar{R}, u^5
2	Sulphydryl, (SH)	\bar{R}	u			\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}, u^5
3	Sulfide, (S)	\bar{R}	u ⁶		u ⁷	\bar{R}, u^8	\bar{R}	\bar{R}	\bar{R}	\bar{R}, \bar{U}
4	Bisulfite, (HSO ₃)	\bar{R}	u ⁹			\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}, \bar{U}
5	Sulfite, (SO ₃)	\bar{R}, u	u ⁹		u ¹⁰	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}, \bar{U}
6	Sulfate, (SO ₄)	U	u ⁹	u	r	U	U	r	\bar{R}	\bar{R}, u^{11}
7	Thiosulfate, (S ₂ O ₃)	\bar{R}, u	rm, u		u ¹²	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}, \bar{U}
8	(S ₂ O ₈) ¹³	\bar{R}	u?			\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
9	Tetrathionate, (S ₄ O ₆)	\bar{R}			u	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
10	Sulfoxylate, (SOOH)	\bar{R}	u ¹⁴		u	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
11	(SO) as Sulfur hydrate, H ₂ SO	\bar{R}			u	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
12	Thiocyanate, (SCN)	\bar{R}	u		u ¹⁵	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
13	Persulfate	\bar{R}	u ⁹			\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
Sulfur Containing Amino Acids, Sulfoproteins ¹⁶										
14	Cystathionine	\bar{R}	u		u	\bar{R}, u^{17}	\bar{R}	\bar{R}, u	u	u
15	Cysteine	\bar{R}, u	u ⁶	u	r	\bar{R}, u^{17}	\bar{R}, u	u	u ¹⁸	U
16	Cystine	\bar{R}, u	u ⁶	u	r	\bar{R}	\bar{R}, u	u	u	U
17	Homocysteine	\bar{R}	U		u	\bar{R}	\bar{R}	\bar{R}, u	u	u
18	Homocystine	\bar{R}	U		u	\bar{R}	\bar{R}	\bar{R}, u	u	u
19	Methionine	\bar{R}, u	U	u	r	\bar{R}, \bar{U}	r	r	r ¹⁹	R
20	Peptones	\bar{R}, u	U	u	u	\bar{R}, u	u	r	u	\bar{R}, U
Sulfur Containing Vitamins and Growth Factors ¹⁶										
21	Biotin ²⁰	\bar{R}	u	u	u	\bar{R}	r	r?	r	R?, U
22	Coenzyme A	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}, U
23	Glutathione ("G-SH") ²¹	\bar{R}	u	u	r	\bar{R}	u	\bar{R}, u	r	\bar{R}, U
24	Thiamine ²²	\bar{R}	\bar{U}	r	r	u	r	r	r	R
25	Thiazole ²²	\bar{R}	u? ²³	r ²⁴	r ²⁴	r	r ²⁴	r ^{24, u}	\bar{R}	\bar{R}
26	Thioctic acid ²⁵	\bar{R}	\bar{R}	\bar{R}	r ²⁶	\bar{R}	\bar{R}	r ²⁷	\bar{R}	\bar{R}
Miscellaneous Sulfur Compounds										
27	Alkylsulfides, R-S-S-R	\bar{R}	u ²⁸			\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
28	Alkylsulfonates, R-SO ₂ -R	\bar{R}	u			\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
29	Alkylsulfonates, R-SO ₃ -R	\bar{R}	u			\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
30	Dithionate	\bar{R}	u ²⁹			\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
31	Ethereal sulfates	\bar{R}	U			\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
32	Sulfamate, (SO ₃ -NH ₂)	\bar{R}	u			\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
33	Sulfonic acid amides	\bar{R}	rm		\bar{U}	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
34	Sulfoxides, R ₂ SO	\bar{R}	u		u	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
35	Taurine	\bar{R}	u		\bar{U}	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
36	Thioacetamide	\bar{R}	u		u	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
37	Thioacetate	\bar{R}	r, u ⁶		u? ³⁰	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
38	Thiocarbonate	\bar{R}	r, u ⁶			\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
39	Thioglycolate	\bar{R}	r, u ⁶		u? ³¹	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
40	Thiols, R-SH	\bar{R}	u			\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
41	Thiooxalate	\bar{R}	u			\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}
42	Thiourea	\bar{R}	u ⁶	u ³²	u? ³³	\bar{R}	\bar{R}	\bar{R}	\bar{R}	\bar{R}

/1/ Including the colorless phytoflagellates. /2/ The substance not in combination with other elements. /3/ U by *Fusarium lini*. /4/ U by *Thiobacillus thio-oxidans*, *Sporovibrio desulfuricans*, *S. aestuarii*, *Thiorhodaceae*. /5/ Bacteria, in ruminants, build the element into amino acids (methionine; cystine). /6/ Some aquatic fungi, e.g., members of the *Blastocladales* and *Saprolegniales*, \bar{U} oxidized sulfur; these require a reduced sulfur source, e.g., H₂S, cysteine, cystine, methionine, thioacetate, thiocarbonate, thioglycolate, thiourea. /7/ U, e.g., by *Beggiatoa*, *Thiothrix*, *Thioploca*, *Thiobacilli*. /8/ *Synechococcus*, grown in an atmosphere of N₂, U Na₂S (with reduction of CO₂); *Oscillaria* and *Pinnularia* also reduce CO₂ with H₂S, depositing S in their cells. *Scenedesmus* also U sulfide. H₂S toxic to *Chlorella*. /9/ U by *Brevilegnia gracilis*; \bar{U} by many other *Saprolegniaceae*. /10/ U by *Sporovibrio desulfuricans*, *S. aestuarii*. /11/ U for formation of chondroitin sulfate and heparin; U by laying hen by conversion to cystine. /12/ U by *Thiobacillus novellus*, *Pseudomonas aeruginosa*, *P. fluorescens*, *Achromobacter stutzeri*, others. /13/ Decomposes on contact with H₂O. /14/ Inorganic sulfur, less oxidized than sulfinate, not efficiently U by *Aspergillus niger*. /15/ NH₄SCN can be U by *Bacillus thio-cyan-oxidans* as sole source of C, N, and S. /16/ R, r, U, u, may mean as a sulfur source, or the compound may be R for its molecular structure, not synthesized by the organism. /17/ U as N-source (and sulfur source?) by *Chlorella pyrenoidosa*. /18/ Also U cysteine acid, isethionine acid. /19/ Also U methionine sulfoxide, taurine. /20/ Biotin R by numerous fungi, yeasts, bacteria and by most of the vertebrates and invertebrates studied. The replacement of S in the biotin molecule does not affect the activity for some bacteria. /21/ Complex of cysteine, glycine, and glutamic acid. /22/ Thiamine, containing pyrimidine and thiazole (the latter an imidazole ring with one C replaced by sulfur), is R by numerous organisms; probably also a sulfur source? /23/ \bar{U} as sulfur source by *Aspergillus niger* (cannot rupture the thiazole ring?). /24/ Satisfies thiamine requirement for some (cf. Fn 22); probably a sulfur source? /25/ = Protogen, or α -lipoic acid. /26/ R by *Streptococcus fecalis* for oxidation of pyruvate. /27/ R by *Tetrahymena geleii* (8 strains), *T. vorax* (2 strains). /28/ U by *Scopulariopsis* (*Penicillium brevicaulis*, *Schizophyllum commune*). /29/ \bar{U} by *Saprolegniaceae*. /30/ \bar{U} as carbon source by many; improbable sulfur source. /31/ Surface active in culture media for many fastidious forms; powerful reducing agent; \bar{U} as carbon source; improbable as sulfur source. /32/ U by *Torula monosa*, *T. dattila*. /33/ U as nitrogen source by many bacteria; probable sulfur source?

187. DIETS, LOW AND MODERATE COST: MAN, U. S. A.

These food plans (low cost=L; moderate cost=M) represent quantities per week, as purchased, that will furnish nutritionally adequate diets as judged by the National Research Council's recommended allowances (1948). Both the low and moderate cost plans have the same adjustment for losses of vitamins in cooking. Values are in kilograms, except for milk (liters) and eggs (number).

Family Members		Leafy, Green and Yellow Vegetables		Citrus Fruit, Tomatoes		Potatoes, Sweet-potatoes		Other Vegetables and Fruit		Milk ¹		Meat, Poultry, Fish		Eggs		Dry Beans and Peas, Nuts		Flour, Cereals ²		Fats and Oils ³		Sugar, Sirups, Preserves	
		kg		kg		kg		kg		L		kg		no.		kg		kg		kg		kg	
		L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M
1	Children 9-12 mo	0.68	0.68	0.79	0.79	0.23	0.23	0.45	0.45	5.68	5.68	0.11	0.11	5	5	0.03	0.03	0.28	0.28	0.03	0.03	0.03	0.03
2	1-3 yr	0.79	0.91	0.79	0.91	0.45	0.23	0.45	0.79	5.20	5.68	0.23	0.34	5	6	0.03	0.03	0.57	0.57	0.06	0.06	0.06	0.06
3	4-6 yr	0.79	1.02	0.79	1.02	0.68	0.45	0.57	1.02	5.20	5.68	0.45	0.57	5	7	0.06	0.03	0.79	0.68	0.17	0.17	0.17	0.23
4	7-9 yr	0.91	1.13	0.91	1.13	1.13	0.79	0.68	1.13	5.20	6.15	0.68	0.79	5	7	0.11	0.06	1.02	0.91	0.23	0.23	0.28	0.34
5	10-12 yr	1.02	1.36	1.02	1.25	1.36	1.02	0.79	1.13	5.68	6.62	0.79	1.02	5	7	0.11	0.06	1.47	1.25	0.34	0.34	0.34	0.40
6	Girls 13-15 yr	1.02	1.59	1.02	1.25	1.47	1.13	0.79	1.59	6.15	6.62	0.91	1.25	5	7	0.11	0.06	1.59	1.25	0.34	0.40	0.34	0.40
7	16-20 yr	1.02	1.59	1.02	1.25	1.36	1.13	0.79	1.59	4.73	5.68	0.91	1.25	5	7	0.11	0.06	1.47	1.13	0.34	0.34	0.28	0.40
8	Boys 13-15 yr	1.13	1.59	1.13	1.36	1.81	1.59	1.02	1.59	6.15	6.62	0.91	1.36	5	7	0.23	0.11	2.04	1.81	0.45	0.51	0.40	0.51
9	16-20 yr	1.25	1.81	1.13	1.59	2.27	2.04	1.13	1.59	6.15	6.62	0.91	1.47	5	7	0.23	0.17	2.61	2.38	0.62	0.62	0.45	0.57
10	Women Sedentary	1.02	1.47	0.91	1.13	1.02	0.79	0.79	1.47	4.73	4.73	0.91	1.13	5	7	0.11	0.03	0.91	0.79	0.28	0.28	0.28	0.34
11	Mod. active	1.02	1.59	0.91	1.13	1.36	1.13	0.79	1.59	4.73	4.73	0.91	1.25	5	7	0.11	0.06	1.47	1.13	0.34	0.40	0.34	0.40
12	Very active	1.13	1.70	1.13	1.36	1.81	1.47	0.91	1.81	4.73	4.73	0.91	1.36	5	7	0.17	0.11	1.93	1.70	0.45	0.51	0.45	0.51
13	Pregnant	1.36	1.81	1.13	1.59	1.13	1.02	0.91	1.36	7.10	7.10	1.02	1.36	7	7	0.11	0.06	1.13	1.02	0.28	0.28	0.23	0.28
14	Nursing	1.59	1.81	1.70	2.04	1.81	1.36	1.02	1.59	9.94	9.94	1.13	1.36	7	7	0.11	0.06	1.36	1.13	0.28	0.34	0.23	0.34
15	60 yr or over	1.13	1.59	1.02	1.25	1.13	0.91	0.79	1.36	4.73	5.20	0.91	1.13	4	6	0.06	0.03	1.02	0.79	0.23	0.23	0.23	0.28
16	Men Sedentary	1.02	1.59	0.91	1.13	1.36	1.13	0.79	1.59	4.73	4.73	0.91	1.25	5	7	0.11	0.06	1.47	1.13	0.34	0.40	0.34	0.40
17	Phys. active	1.13	1.70	1.13	1.36	1.81	1.47	0.91	1.81	4.73	4.73	0.91	1.36	5	7	0.17	0.11	1.93	1.70	0.45	0.51	0.45	0.51
18	Heavy work	1.13	1.81	1.13	1.59	2.72	2.27	1.13	1.93	4.73	4.73	0.91	1.59	5	7	0.28	0.17	3.52	3.18	0.85	0.91	0.45	0.57
19	60 yr or over	1.13	1.59	1.02	1.25	1.47	1.25	0.79	1.36	4.73	5.20	0.91	1.25	4	6	0.06	0.06	1.47	1.13	0.28	0.34	0.28	0.34

/1/ Or its equivalent in cheese, evaporated milk, or dried milk. /2/ Count 0.68 kg bread as 0.45 kg flour. /3/ For small children, and pregnant and nursing women, cod-liver oil or some other source of vitamin D is also needed. For elderly persons and those who have no opportunity for exposure to clear sunshine, a small amount of vitamin D is also desirable. /4/ To meet iron allowance, 1 large or 2 small servings of liver or other organ meats should be served each week.

188. DIETS: LABORATORY AND DOMESTIC ANIMALS

These diets have been selected from a large number of possible diets. They are not necessarily optimal, nor do they suit all conditions and feeding purposes. Consult texts on feeding for more detailed information. Unless otherwise indicated, values are grams per 100 grams of ration, the daily food or feed intake is expressed as kg per animal, and the values are for adult animals.

Animal	Intake ¹ , kg	Diet
1 Cattle, beef ² , 408 kg	I-9.4; II-9.0; III-17.9	Diet I: alfalfa hay, 20; oat hay, 80. Diet II: corn fodder, 50; barley straw, 25; alfalfa hay, 25. Diet III: corn silage, 69; oat straw, 27; cottonseed meal (41% protein), 4.
2 Chicken, Rhode Island Red ³ , 2.5 kg	0.092	Corn, ground yellow, 49; standard wheat middlings, 15; wheat bran, 10; alfalfa meal, 5 (meal contains 75,000 or more I. U. of vitamin A per lb); soybean oil meal, 4; fish meal, 4; meat meal, 4; dried whey, 4; steamed bone meal, 1; ground limestone, 3.5; salt, 0.5; vitamin A and D feeding oil (300 International Chick Units vitamin D, 1500 I. U. vitamin A, per gram), 0.3; anhydrous MnSO ₄ , 0.0125 g, and riboflavin 0.1 mg per 100 g feed.
3 Dog ⁴	Varies with breed	Meat, meat by-products including bone, or fish, 20; soybean meal, wheat germ, corn germ, or nut meal, 20; corn, wheat, or barley, 50; carrots, beet by-products, or tomato by-products, 2-5; iodized salt, 0.24-0.5; milk, liver meals, or fermentation solubles, q. s.; fish liver oils and irradiated yeast, q. s.
4 Fish ⁵ , 0.002-0.05 kg	0.04-3 at 10°C	Diet I: pork or beef spleen, 35; beef liver, 15; salt, 2; fish meal, 12; wheat middlings, 12; dried skim milk or distillers' solubles, 12; cottonseed meal, 12. Diet II: beef liver, 33; beef spleen, 33; horse meat, 34. Diet III: spoked carp or other rough fish, 45; oatmeal, 5; beef liver, 15; beef or pork spleen, 35.
5 Horse ⁶ , 544 kg	11.4	Timothy hay, 26; alfalfa hay, 20; oats, 32; corn, 22.
6 Monkey ⁷ , 1.5-3 kg	0.06-0.12	Sucrose, 71; "de-vitaminized" casein, 18; corn oil, 4; salt mixture, 3 (composed of CaCO ₃ , 300 g; K ₂ HPO ₄ , 470 g; CaHPO ₄ , 680 g; MgSO ₄ , 100 g; NaCl, 670 g; KCl, 115 g; FeC ₆ H ₅ O ₇ , 55 g; KI, 1.6 g; MnSO ₄ ·H ₂ O, 9 g; ZnCl ₂ , 4 g; CuSO ₄ , 2.4 g; CoCl ₂ , 0.2 g); whole liver substance, 2; liver concentrate powder, 2. To each 18 g of casein, add: thiamine hydrochloride, 350 µg; pyridoxine hydrochloride, 350 µg; nicotinamide, 2.5 mg; choline chloride, 100 mg; inositol, 100 mg; para-aminobenzoic acid, 30 mg; calcium pantothenate, 2 mg; riboflavin, 350 µg; folacin, 200 µg; biotin, 20 µg; ascorbic acid, 10 mg. To each 4 g of corn oil, add: 90% β-carotene, 90 µg; calciferol, 0.8 µg; α-tocopherol, 5 mg; menadione, 100 µg.
7 Rat ⁸ , 0.18 kg	0.007	Casein, 35; corn starch 37; lard, 15; butter fat, 9; salt mixture, 4 (composed of CaCO ₃ , 134.8 g; Na ₂ CO ₃ , 34.2 g; MgCO ₃ , 24.2 g; K ₂ CO ₃ , 141.3 g; H ₃ PO ₄ , 103.2 g; HCl, 53 g; H ₂ SO ₄ , 9.2 g; citric acid·H ₂ O, 111 g; Fe citrate·xH ₂ O, 6.3 g; KI, 0.02 g; MnSO ₄ , 0.079 g; NaF, 0.248 g; K ₂ Al ₂ (SO ₄) ₄ , 0.0245 g). To this ration, add 0.5 g yeast, 25 g lettuce.
8 Sheep ⁹ , 32 kg	I-3.8; II-1.2; III-1.5	Diet I: barley (corn, oats, or sorghum), 10.1; beet pulp, wet, 70; alfalfa hay, 20. Diet II: corn (barley or sorghum), 42; alfalfa, 58. Diet III: corn, 32; soybean oil meal, 5.9; alfalfa hay, 32; corn silage, 30.
9 Swine ¹⁰ , 45 kg	I, II, III, IV, or V-2.4	Diet I: corn (yellow), 63; oats, 15; soybean meal, 7.8; middlings, 5.0; meat scrap, 3.0; alfalfa meal (dehydrated), 5.0; limestone, 0.7; salt, 0.5. Diet II: barley, 50; oats, 40; linseed meal, 3.0; fish meal, 1.0; meat scrap, 3.0; minerals (iodized salt, 20%; steamed bonemeal, 37.7%; ground limestone, 40%; ferrous sulfate, 2%; manganese sulfate, 0.2%; copper sulfate, 0.1%), 3.0; A and D oil (to supply 45,000 I. U. vitamin A and 9,000 I. U. vitamin D per 45 kg of feed). Diet III: barley, 83; tankage, 3; soybean meal, 8; alfalfa meal (deh.), 4.5; bone meal, 0.5; limestone, 0.5; salt, 0.5. Diet IV: corn, 82; soybean meal, 6.5; meat and bone scrap, 2.5; fish meal, 2.5; cottonseed meal, 2.5; alfalfa meal (deh.), 2.5; limestone, 0.5; bone meal, 0.5; salt, 0.5. Diet V: corn, 79; soybean meal (solvent extracted), 13.5; alfalfa meal (sun cured), 5.0; mineral mix (same as Diet II), 2.0; vitamin mix (each lb contains riboflavin, 200 mg, pantothenic acid, 500 mg; B ₁₂ , 2 mg; and an antibiotic in an amount suited to its kind).

/1/ The numerals I, II, etc., refer to alternative dietary mixtures given in column C. /2/ Wintering pregnant cow. /3/ Mature, breeding. /4/ For more detailed diets, see Report of Committee on Animal Nutrition, National Research Council, 8, Dec. 1953. /5/ Brook, brown and rainbow trout, age 3-9 months. /6/ Lactating mare. /7/ Rhesus, juvenile. /8/ White, age 1-6 months. /9/ Fattening lambs. /10/ About 1/4 grown.

189. DIETS: ZOO ANIMALS
Part I: ZOO DIETS: MAMMALIA AND AVES

Diets illustrate the feeding practices successfully in use in the New York, Chicago, and San Diego zoological parks. Differences in diet reflect climatic conditions, food availability, and individual variation within species. Body weights and feed values are estimates and are for a single animal of the species listed.

	Species	Zoo ¹	Sex	Body Weight lb	Total Feed ² lb/wk	Horse Meat lb/wk	Liver, Kidney lb/wk	Composition of Diet	
								Miscellaneous lb/wk ³	
1	Monotremata Platypus (<i>Ornithorhynchus anatinus</i>)	NY	M	3.3				Earthworms, 7; crayfish (105-140); mealworms (1400); frogs (14); eggs (14).	
2	Marsupialia Kangaroo, red (<i>Macropus rufus</i>)	SD	M	54	57			Alfalfa, 21; apples, 7; bread, 5; lettuce, 21; browse, 3.	
3		NY	M	130	49.1			Rolled oats, 5.3; apples, 3.5; bananas, 1.8; bread, 3.5; cabbage, 2.1; carrots, 3.5; crushed oats, 1.4; clover hay, 21; lettuce, 3.5; white potatoes, 3.5.	
4	Wombat (<i>Vombatus hirsutus</i>)	NY	F	20	10.3			Rolled oats, 1; apples, 3.5; bananas, 0.7; bread, 2.1; carrots, 1; crushed oats, 1; white potatoes, 1.	
5	Primates Gorilla, lowland (<i>Gorilla gorilla</i>)	NY	F	296	53.9 ⁴	2.3		Powdered whole milk, 1; cereal, 1; malted milk powder, 0.2; honey, 42 g; eggs, 1.4; sugar, 0.6; dicalcium phosphate, 14 g; carrots, 17; celery, 3.5; bananas, 7; oranges, 2.7; apples, 5.4; cabbage, 1.8; lettuce, 2.3; grapes, 2.3; sweet potatoes, 2.3; green beans, 2.3; spinach, 0.5; scallions, 0.3; vitamins, 12 drops. ⁴	
6	Mandrill (<i>Mandrillus sphinx</i>)	SD	M	25	25.6			Apples, 5.3; bread, 0.8; fruit, 5.3; sweet potatoes, 0.1; lettuce, 5.6; onions, 0.5; corn, 2; tomatoes, 3.5; avocados, 1.5; string beans, 1.	
7	Orangutan (<i>Pongo pygmaeus</i>)	NY	M	105	31.5 ⁴	7.0		Apples, 3.5; bananas, 5.3; bread, 0.8; cabbage, 1.8; carrots, 8.8; eggs (14); grapes, 0.8; lettuce, 3.5; dog biscuit ⁵ , (28); milk mixture ⁶ , 7 gal.	
8		SD	M	150	60.6	1.8		Bread, 2.1; fruit, 10.5; string beans 2.3; tomatoes, 10.5; lettuce, 8.8; sweet corn, 1.5; bananas, 1.8; sweet potatoes, 3.9; grapes, 1.5; milk, 0.6; peanuts, 0.8; avocados, 3.0; rice & raisins, 1.	
9	Carnivora Badger, Canadian (<i>Taxidea taxus</i>)	SD		30	6			Dog food mix ⁷ , 6.	
10	Bear, Eurasian brown (<i>Ursus arctos</i>)	SD	M	450	72 ⁴	15		Mackerel, 21; eggs (24); lettuce, 1.5; apples, 1.5; fruit, 3; bran & honey ⁸ , 3; celery, 9; bread, 12; tomatoes, 1.5; avocados ⁹ , 4.5.	
11	Bear, grizzly (<i>Ursus horribilis</i>)	SD	M	700	85.5 ⁴	24		Mackerel, 12; eggs (24); lettuce, 3; apples, 3; fruit, 4.5; bran & honey ⁸ , 6; celery, 13.5; bread, 12; tomatoes, 1.5; avocados ⁹ , 6.	
12	Bear, kodiak (<i>U. middendorffii</i>)	NY	M	800	132-150	42		Butterfish, 30; mackerel, 30; apples, 18; bread ¹⁰ , 12.	
13	Bear, polar (<i>Thalarctos maritimus</i>)	SD	F	300	76.5 ⁴	24		Mackerel, 2.4; eggs (36); apples, 3.6; fruit, 9; bran & honey ⁸ , 9; celery, 13.5; bread, 9; tomatoes, 1.5; avocados, 4.5.	
14	Bear, sloth (<i>Melursus ursinus</i>)	SD	F	350	13.5-15	4.5		Eggs (24); lettuce, 1.5; fruit, 3; bran & honey ⁸ , 3; avocados ¹¹ , 3.	
15	Cheetah (<i>Acinonyx jubatus</i>)	SD	M	120	38	35	1	Jungle fowl, rabbit, or guinea pig, 2.	
16	Dingo (<i>Canis dingo</i>)	SD	M	50	25 ⁴	2.5	1	Dog food mix ⁷ , 12.5; jungle fowl, rabbit, or guinea pig, 2; milk, 7; eggs (12).	
17	Fox, Arctic (<i>Alopex lagopus ungava</i>)	SD		15	6			Dog food mix ⁷ , 6.	
18	Hyena, spotted (<i>Crocuta crocuta</i>)	SD	M	100	18	15	1	Jungle fowl, rabbit, or guinea pig, 2.	
19	Jaguar (<i>Panthera onca</i>)	SD	M	175	33	30	1	Jungle fowl, rabbit, or guinea pig, 2.	
20		NY	M	175	39.5 ⁴	34	5	Bone meal, 0.5; cod-liver oil, 48 ml.	
21		LP	M	18 ⁴	18			Vitamin and mineral supplement.	
22	Leopard (<i>Panthera pardus</i>)	SD	M	120	33	30	1	Jungle fowl, rabbit, or guinea pig, 2.	
23		NY	F	125	22.7 ⁴	21.5	1	Bone meal, 0.2; cod-liver oil, 30 ml.	
24		LP	M	9 ⁴	9			Vitamin supplement.	
25	Lion (<i>Panthera leo</i>)	SD	M	250	75	72	1	Jungle fowl, rabbit, or guinea pig, 2.	
26		NY	M	350	57.5 ⁴	55	2	Bone meal, 0.5; cod-liver oil, 57 ml.	
27		LP	F	45 ⁴	45			Vitamin and mineral supplement.	
28	Lynx, Yukon (<i>Felis canadensis mollipilosus</i>)	SD		35	14.4 ⁴	12		Eggs (6); milk, 2.4.	
29	Ocelot (<i>Felis pardalis</i>)	SD		16	12	10	2		
30	Panda, lesser (<i>Ailurus fulgens</i>)	SD		14	18 ⁴			Milk, 3.5; eggs (14); apples, 1.75; fruit, 1.75; dates, 1.75; raisins, 0.4; grapes, 1.75; bananas, 7; Pabulum, 0.1; fresh bamboo, ad lib.	
31	Raccoon (<i>Procyon lotor</i>)	LP		4.8	3.6			Whole wheat bread, 1.2.	
32	Tiger, Bengal (<i>Panthera tigris</i>)	SD	M	350	87	84	1	Jungle fowl, rabbit, or guinea pig, 2.	
33	Wolf, N. American (<i>Canis lupus nubilus</i>)	SD	M	80	33	5	1	Dog food mix ⁷ , 25; jungle fowl, rabbit, or guinea pig, 2.	
34	Pinnipedia Sea lion (<i>Zalophus californianus</i>)	NY	M	600	96			Butterfish, 48; mackerel, 24; smelts, 24.	
35	Seal, harbor (<i>Phoca vitulina geronimensis</i>)	NY	F	70	28			Mackerel, 28.	
36	Rodentia Chinchilla	LP		1.25	9 oz			Rabbit chow (Purina), 3.1 oz; timothy hay, 2.7 oz; carrots, 1.8 oz; rolled oats, 0.4 oz; yellow corn, 0.4 oz; wheat germ, 0.05 oz; flax seed, 0.1 oz; CaHPO ₄ , 0.1 oz; raisins, 0.03 oz; oyster shells, 0.1 oz; apple bark, 0.2 oz.	

Proboscidea							
37	Elephant, Indian (<i>Elephas maximus</i>)	SD	F	4500	879		Grain mix ¹² , 28; avocados ¹³ , 15; celery, 70; apples, 35; oat hay, 630; bread, 14; sweet corn ¹⁴ , 105.
38		NY	F	5500	846-966		Alfalfa ¹⁵ , 350; timothy ¹⁵ , 490; GLF ¹⁶ , 42; crushed oats, 38.5; bread, 15; cabbage, 15; potatoes, 15.
39		LP	F				Apples (168); rye or whole wheat bread, 42; carrots, 168 qt; beets, 1.6 bu; timothy, 560; alfalfa, 28; oats, 7 pk; bran, 7 pk; cornstalks.
Artiodactyla							
40	Alpaca (<i>Lama pacos</i>)	SD	M	200	45		Alfalfa pellets ¹⁷ , 14; grain mix ¹² , 6; avocados ¹³ , 6; lettuce, 3; carrots, 9; browse, 7.
41	Antelope, sable (<i>Hippotragus niger roosevelti</i>)	SD	M	550	86		Alfalfa pellets ¹⁷ , 49; grain mix ¹² , 6; avocados, 6; carrots, 6; celery, 9; browse, 10.
42	Buffalo, African (<i>Syncerus caffer</i>)	SD	M	3600	402±		Alfalfa pellets ¹⁷ , 350; grain mix ¹² , 12; avocados ¹³ , 15; browse, 25 (occasionally).
43		NY ¹⁸	M	1400	252.8±		Clover, 140; GLF ¹⁶ , 26.3; crushed oats, 24.5; cabbage, 51.5; lettuce, 10.5; green leaves 1 or 2 x/wk.
44	Camel, dromedary (<i>Camelus dromedarius</i>)	NY ¹⁸	F	1310	140		Clover, 105; GLF ¹⁶ , 35.
45	Deer, red (<i>Cervus elaphus</i>)	SD	F	350	93		Alfalfa pellets ¹⁷ , 35; grain mix ¹² , 6; avocados, 6; carrots, 6; celery, 30; browse, 10.
46	Giraffe, uganda (<i>Giraffa camelopardalis rothschildii</i>)	SD	M	2500	622.9		Alfalfa pellets ¹⁷ , 105; grain mix ¹² , 45; carrots, 60; apples, 90; potatoes, 42; onions, 35; tea, 0.9; acacia browse, 245.
47		NY ¹⁸	F	1300	254.3		Clover, 140; GLF ¹⁶ , 31.5; crushed oats, 31.5; apples, 2.3; bananas, 14; bread, 21; cabbage, 3.5; white potatoes, 5.6; carrots, 3.5; lettuce, 1.4.
48	Hippopotamus (<i>Hippopotamus amphibius</i>)	SD	M	4000	693		Alfalfa pellets ¹⁷ , 420; grain mix, 18; avocados, 15; lettuce, 60; celery, 60; sweet corn, 120.
49	Llama (<i>Lama glama</i>)	SD	M	275	90		Alfalfa pellets ¹⁷ , 35; grain mix, 6; avocados, 9; carrots, 30; browse, 10.
50		NY ¹⁸	M	285	59.5		Clover, 38.5; GLF ¹⁶ , 14; crushed oats, 7.
51	Moose (<i>Alces americana</i>)	SD	M	750	609		Grain mix ¹² , 91; avocados, 21; lettuce, 42; carrots, 60; apples, 150; browse, 245.
Perissodactyla							
52	Rhinoceros, black (<i>Rhinoceros bicornis</i>)	NY	M	2800	615.5		Alfalfa ¹⁵ , 140; timothy ¹⁵ , 210; GLF ¹⁶ , 10.5; bread, 210; cabbage, 15; carrots, 15; potatoes, 15.
53	Zebra, Chapman (<i>Equus burchelli antiquorum</i>)	SD	M	600	124		Alfalfa pellets ¹⁷ , 7; grain mix ¹² , 6; carrots, 6; oat hay, 105.
54		NY	F	650	90.3		Timothy, 70; crushed oats, 16.8; carrots, 3.5.
Struthioniformes							
55	Ostrich, N. African (<i>Struthio camelus</i>)	SD	M	250	28.8±	7	Bread, 5.3; lettuce, 6; alfalfa, 3.5; barley, 7; oyster shell.
Causariiformes							
56	Cassowary (<i>Casuarus unappendiculatus occipitalis</i>)	SD	F	100	45.6±	1.8	Apples, 14; bananas, 7; mice (28); fruit, 14; tomatoes, 8.8.
57	Emu (<i>Dromiceus novaehollandiae</i>)	SD	M	100	29.8	1.8	Bread, 5.2; lettuce, 7; barley, 7; apples, 8.8.
58		NY		60	22.1±	1.3	Apples, 3.5; bread, 7; lettuce, 5.2; rolled oats, 2.5; GLF ¹⁶ , 2.6; whole corn, 7 pt in winter; scratch, 7 pt in summer.
Sphenisciformes							
59	Penguin, king (<i>Aptenodytes p. patagonica</i>)	NY		45	24.5±	19	Mackerel, 24.5.
Pelecaniformes							
60	Pelican, European white (<i>Pelecanus occidentalis onocrotalus</i>)	SD		15	17.5		Anchovies & sardines, 17.5.
61		NY		14	15.6±	20	Butterfish ²¹ , 15.6.
Ciconiiformes							
62	Heron, cocoi (<i>Ardea cocoi</i>)	NY		5	3		Butterfish, 3.
63	Shoebill (<i>Balaeniceps rex</i>)	SD	F	12	16		Anchovies & sardines, 7; liver, 9.
64		NY		16	12.5		Butterfish, 12.5.
Falconiformes							
65	Condor, Andean (<i>Vultur gryphus</i>)	SD		50	14		Anchovies & sardines, 14.
66		NY		22	10	10±	Rats (2) instead of horse meat 2 x/mo.
67	Eagle, bald (<i>Haliaeetus leucocephalus</i>)	SD		6	3.5		Anchovies & sardines, 3.5.
68		NY		12	5.8	3.8	Butterfish, 2.
Strigiformes							
69	Owl, snowy (<i>Nyctea scandiaca</i>)	SD		3	2.5±		Anchovies & sardines, 2.5.
70		NY		3	2.5	2.5	Rat (1).
Micropodiformes							
71	Hummingbird, ruby-throated (<i>Archilochus colubris</i>)	NY		2.5 g	122 ml		Mellin's formula ²² , 112 ml; honey formula ²³ , 9.8 ml.

/1/ NY=New York Zoological Park, New York, N.Y.; SD=San Diego Zoological Gardens, San Diego, California; LP=Lincoln Park Zoo, Chicago, Illinois. /2/ Based on 7 da/wk feeding except for the order Carnivora in which the animals are fed 6 da and fasted the 7th. /3/ Lb/wk, unless otherwise indicated; figures in parentheses are no./wk. /4/ Vitamin formula: A, 5000 USP units; D₃, 1000 USP units; B₁, 1.0 mg; B₂, 1.0 mg; B₆, 0.5 mg; calcium pantothenate 3.0 mg; nicotinamide, 10.0 mg; ascorbic acid, 60.0 mg; B₁₂, 1.0 µg; folic acid, 0.25 mg. /5/ Dog biscuit formula: wheat flour, meat meal, bone meal, wheat bran, wheat germ meal, tomato pulp, irradiated dried yeast; dried corn fermentation solubles, calcite flour, manganese sulphate, potassium iodide, iron sulphate, copper carbonate, salt, Vitamin A feeding oil, dried skim milk, Brewer's yeast, turmeric, charcoal. Protein, 20%; fat, 1%; fiber, 2%. /6/ Milk mixture formula: salt, 2 t; sugar, 2 T; malted milk powder, 2 t; cereal, 1½ lb; evaporated milk, 26 oz; water, 26 oz. /7/ Dog food mix (lbs): meat, 100; kibbled dog biscuit, 25; powdered milk, 5; bone meal, 5; NaCl, 1; water, 5 gal. /8/ Equal parts honey and bran. /9/ In winter only. /10/ 30 lb in summer. /11/ 1.5 lb in summer. /12/ Grain mix formula (lbs): beet pulp, 300; rolled barley, 300; bran, 100; rolled oats, 75; ground corn, 100; linseed meal, 40; bone meal, 5; salt, 5; live yeast culture, 3. /13/ 9 lbs in winter. /14/ During corn season. /15/ Hay consumption is decreased 25% in summer months. /16/ GLF formula (lbs): 34% linseed meal, 200; wheat bran, 200; hominy feed and corn meal, 400; crushed oats, 419.5; cane molasses, 200; beet pulp, 200; chopped alfalfa, 240; wheat germ meal, 60; Brewer's yeast, 40; irradiated yeast, 0.5; salt, 20; dicalcium phosphate, 15; ground limestone, 5. /17/ Fresh-cut alfalfa, approximately twice the amount of alfalfa pellets, is fed 3 da per week for 10 months of the year in place of alfalfa pellets. /18/ Salt block available. /19/ Eats almost twice as much for 10 da before and after annual moult; during moult, almost complete inappetence. /20/ Eats about 50% more daily for 2 autumn months. /21/ 23 lb in winter. /22/ Mellin's formula (given in a.m.): Mellin's food, 4 t; honey, 5 t; condensed milk, 1 t; vitamins, 4 drops; beef extract, 5 ml; warm water, 1 qt. /23/ Honey formula (given in p.m.): honey, 5 t; beef extract, 5 ml; vitamins, 4 drops; warm water, 1 qt.

189. DIETS: ZOO ANIMALS (Concluded)

Parts II and III list diets, as developed and used by the Philadelphia Zoological Garden, for captive wild animals. Although the diets are completely adequate for the majority of animals given below, certain rare species have not been tested.

Part II: BASIC DIETS

Values are g/100 g of ration, unless otherwise indicated.

Ingredient	Diet A ¹	Diet B	Diet C	Diet D	Diet E	Diet F
1 Basic Mixture			31 ²	50 ²		
2 Ground yellow corn	15	15				
3 Ground whole wheat	15	10				
4 Ground whole barley	10					
5 Ground rolled oats	10	10				
6 Peanut meal	10					
7 Soybean meal	10	10				
8 Brewers' yeast	10	5				
9 Dried skimmed milk	10					
10 Alfalfa leaf meal	5	26				
11 Oystershell flour	2	2.5	2		2	
12 Iodized salt	1	1				
13 A-D feeding oil	2	0.5	2	3	2	
Additional						
14 Linseed meal		10				
15 Brewers' grains		10				
16 Dry beet pulp ³		45% ⁴				
17 Whole milk					2x/day	
18 Ground cooked meat	1:9 Basic Mix. ⁵			20		
19 Raw horse meat			55 ⁶			20-100 ⁷
20 Ground raw meat					90	
21 Raw liver						10-50 ⁸
22 Chopped raw cabbage		5%				
23 Ground raw carrots		5%	10	20		
24 Hard-cooked eggs, shells ⁶				7		
25 Deterioration	2 wk ⁹	2 wk ⁹	48 hr ⁹	48 hr ⁹		

/1/ Press and refrigerate 24-28 hr before using. /2/ Basic mixture for Diet A.
/3/ Mix with equal amounts water; let stand 1-2 hr before adding to other ingredients. /4/ Of total dry weight. /5/ Plus broth to make stiff mash.
/6/ Ground. /7/ Or whole or beef, g/kg per body weight, daily. /8/ g/kg body weight, twice weekly. /9/ Refrigerated.

Part III: ANIMAL FEEDING

Diets are for adult animals, unless otherwise indicated.

Animal	Diet ¹	Animal	Diet ¹	Animal	Diet ¹
Omnivorous ²		Omnivorous ² (concluded)		Carnivorous ⁷ (concluded)	
Mammalia		Aves (concluded)		Aves (concluded)	
1 Primates A,S-1	18	Eurypygidae 1/2A,1/2C;S-1	34	Strigiformes C	
2 Rodentia A,S-1	19	Cariacidae 1/2A,1/2C;S-1	35	Ardeidae C	
3 Hyracoidea A,S-1	20	Psophiidae A,S-1	36	Cochleariidae C	
4 Ursidae 1/2A,1/2 raw meat or fish; S-1	21	Herbivorous Mammalia ⁵	37	Laridae C	
5 Suidae A,S-1	22	Artiodactyla ⁶ B,S-2,S-3	38	Corvidae C	
6 Tayasuidae A,S-1	23	Proboscidea B,S-2,S-3	39	Reptilia	
7 Aves	24	Perissodactyla B,S-2,S-3	40	Iguanidae C	
Struthioniformes 1/2A,1/2B;S-1	25	Hippopotamidae B,S-2,S-3	41	Heloderma C	
8 Rheiformes 1/2A,1/2B;S-1	26	Macropodidae B,S-2,S-3	42	Testudinidae C	
9 Psittaciformes ³ A,S-1	27	Carnivorous ⁷	43	Eumeces C	
10 Casuariiformes A,S-1	28	Mammalia	44	Ophisaurus C	
11 Phasianidae A,S-1	29	Viverridae C	45	Aves (Cage) ^{7,9}	
12 Columbidae A,S-1	30	Canidae C	46	Passeriformes D,S-5	
13 Anatidae A,S-1	31	Felidae,immature E	47	Trogoniformes D,S-5	
14 Threskiornithidae 1/2A,1/2C;S-1	32	Felidae ⁸ , adult F	48	Musophagidae D,S-5	
15 Phoenicopteridae ⁴ A,S-1	33	Mustelidae C,S-4	49	Momotidae D,S-5	
16 Gruidae A,S-1		Procyonidae C,S-4	50	Coraciidae D,S-5	
17 Rallidae A,S-1		Didelphiidae C	51	Bucerotidae D,S-5,S-6	
		Aves		Capitonidae D,S-5	
		Falconiformes C		Rhamphastidae D,S-5	

/1/ Diets may be supplemented: S-1=citrus fruits, green vegetables, carrots (for bulk, increase these items); S-2=hay, q.s., green leaves, or fresh-cut grass (5-10g/kg body weight); S-3=equal quantities apples, carrots, green lettuce, or cabbage (10-50 g/kg); S-4=apples and carrots; S-5=oranges, apples, grapes, cherries, and green lettuce; S-6=1-2 mice. /2/ Daily intake: 5-50 g/kg of body weight, depending on weight and activity. /3/ Small lorries and parakeets need whole seed also. /4/ To start on diet, form a mash with water. /5/ Daily food intake: 10-40 g/kg of body weight. /6/ Except swine. /7/ Daily food intake: 25-75 g/kg of body weight. /8/ Daily food intake: 20-100 g/kg of body weight with twice-weekly supplement of liver (see Part II, Diet F). /9/ Diet D may be combined with Diet C in varying proportions.

190. SYNTHETIC DIET MEDIA: INSECTS

These are representative diets for a number of insects studied in nutritional research. Values for sterile diets are in brackets; insects maintained on sterile diets are from bacteria-free eggs. All values calculated (and rounded) as grams or milligrams per 100 grams or milliliters of diet.

Nutrient	Orthoptera	Coleoptera	Lepidoptera				Diptera			
	Cockroach, German (<i>Blattella germanica</i>) ¹ per 100g	Meal Worm, Yellow (<i>Tenebrio molitor</i>) ^{2,3} per 100 g	Flour Moth (<i>Ephestia</i> sp) ² per 100g	Corn Borer (<i>Pyrausta nubilalis</i>) ² per 100g ⁴	Rice Stem Borer (<i>Chilo sim- plex</i>) ² per 100ml ⁴	Bollworm, Pink (<i>Pectinophora gossypiella</i>) ² per 100ml ⁴	Fruit Fly (<i>Drosophila melanogaster</i>) ² per 100ml ⁴	Mosquito, "Yellow Fever" (<i>Aedes aegypti</i>) ² per 100ml	Onion Maggot (<i>Hydomya antiqua</i>) ² per 100ml ⁴	Parasite of Spruce Budworm (<i>Pseudosar- cophaga affinis</i>) ² per 100ml ⁴
1 Calcium chloride, mg							[1.3]	[1.2]		
2 Iron sulfate (ferrous), mg							[1.3]	[1.2]		
3 Magnesium sulfate·7H ₂ O, mg							[25.0]	[20.0]		
4 Manganese sulfate·7H ₂ O, mg							[1.3]	[1.2]		
5 McCollum's salt mixture, g		2.0	2.0			[+] ⁵				[0.172]
6 Potassium hydroxide, g							[61]	[60]		
7 Potassium orthophosphate (mono-H), mg							[61]	[60]		
8 Potassium orthophosphate (di-H), mg							[1.3]	[1.2]		
9 Sodium chloride, mg										
10 U.S.P. salt mixture No.1, g	[3.0]									
11 U.S.P. salt mixture No.2, g									[0.2]	[0.066]
12 Wesson's salt mixture, g	4.0			[0.30]	[0.6]	[0.7]				
13 Casein ⁶ , g	30[29]	17.0	17.0	[4.0]		[5.0]		[0.6]		
14 Cystine, mg						[100]		[20.0]		
15 Glutathione, mg								[1.0]		
16 Glycine, mg						[150]				
17 Amino acid mixture, g					[3.5] ⁷		[3.1] ⁸		[2.4] ⁷	[2.0] ⁷
18 Inosine, mg								[3.0]		
19 Ribonucleic acid, g	[0.5]						[0.1]	[0.1]	[0.1]	[0.1]
20 Thymine, mg									[0.4]	
21 Dextrin, g	[63]									
22 Glucose, g	31	69.0	68	[4.0]	[5.0]				[1.5]	[0.5]
23 Sucrose, g					[2.0]	[8.0]	[0.75]	[0.2]		
24 Cholesterol ⁹ , g	1.0[0.5]	0.9	1.0	[0.15]	[0.06]	[0.3]	[0.04]	[0.003]	[0.01]	[0.1]
25 Ergosterol, g	[0.5]									
26 Linoleic acid, g				[0.15]						
27 Oil, corn, g	3.0					[1.0]				
28 Oil, soybean, g	[1.0]									
29 Oil, wheat germ, g			1.0							
30 Fatty acid mixture ¹⁰ , g										[0.4]
31 Biotin, mg	0.06[0.025]	0.02	0.02		[0.05]	[0.002]	[0.02]	[0.005]	[0.002]	[0.0001]
32 Cobalamin (vitamin B ₁₂), mg						[0.002]	[0.003]		[0.004]	
33 Choline chloride, mg	400[100]	30.0	50	[0.06]	[10.0]	[100]	[7.5]	[2.0]	[2.0]	[9.8]
34 Inositol, mg	200[97]		50		[5.0]			[4.0]		[9.8]
35 Niacin, mg	10.0[10.0]	1.6	5.0		[0.5]	[4.0]		[0.2]	[1.0]	[1.5]
36 Niacinamide, mg							[1.0]	[1.0]		
37 Pantothenic acid (Ca salt), mg	4.0[10.0]	0.8	5.0		[0.5]	[2.0]	[0.6]	[0.6]	[0.6]	[1.5]
38 Para-aminobenzoic acid, mg	[10.0]				[0.5]			[0.2]		[1.5]
39 Pyridoxine (HCl), mg	1.6[10.0]	0.2	5.0		[0.25]	[0.5]	[0.3]	[0.4]	[3.0]	[1.5]
40 Pyridoxamine (HCl), mg								[0.002]		
41 Riboflavin, mg	1.8[10.0]	0.2-0.8	5.0		[0.25]	[1.0]	[0.24]	[0.2]	[0.24]	[1.5]
42 Thiamine (HCl), mg	1.2[10.0]	0.1	5.0		[0.5]	[0.5]	[0.15]	[0.2]	[0.15]	[0.5]
43 Brewer's yeast, g				[1.5]						
44 Carnitine, mg		0.15								
45 Co-enzyme A, mg									[0.15]	
46 Leaf factor, g				[1.2]						
47 Pteroylglutamic acid, mg	0.5[0.4]	0.0125-0.025	0.2		[0.05]	[0.5]	[0.6]	[0.06]	[0.6]	[0.5]
48 Thiocetic acid, mg									[0.05]	
49 Agar-agar, g				[2.3]	[1.0]	[3.0]	[2.0]		[2.0]	[0.75]
50 Cellulose, g	30			[1.8]	[3.0]	[4.0]				
51 Sodium alginate, g						[0.5]				
52 Water, ml	[2.0]	9.0		[100]	[100]	[100]	[100]	[100]	[100]	[100]

/1/ Nymphs and adults. /2/ Larvae. /3/ Also for confused flour beetle (*Tribolium confusum*), except that carnitine is not required, and for *Palorus ratzburgi*. /4/ Agar base. /5/ 2 M solution to adjust pH to 6.5. /6/ Vitamin free. /7/ Mixture of 19 pure amino acids. /8/ Mixture of 18 pure amino acids. /9/ Cholesterol essential for all insects critically studied. /10/ Mixture of palmitic, stearic, oleic, linoleic and linolenic acids.

191. CULTURE MEDIA: PLANT TISSUES

Component	Gautheret ¹ mg/L	White ² mg/L	Component	Gautheret ¹ mg/L	White ² mg/L
1 Ca(NO ₃) ₂ ·4H ₂ O	285	288	13 MnSO ₄ ·4H ₂ O	0.4	4.5
2 CaSO ₄	0.2		14 NiCl ₂	0.01	
3 Fe ₂ (SO ₄) ₃ ·6H ₂ O	20	2.5	15 KI		0.8
4 MgSO ₄ ·7H ₂ O	72	360	16 Ti ₂ (SO ₄) ₃	0.8	
5 KCl	72	65	17 ZnSO ₄ ·7H ₂ O	0.2	1.5
6 KNO ₃	72	80	18 Glucose	20,000	
7 KH ₂ PO ₄ ·H ₂ O	72		19 Sucrose		20,000
8 NaH ₂ PO ₄ ·H ₂ O		16.5	20 Niacin		1.0
9 Na ₂ SO ₄		200	21 Pyridoxine		0.1
10 H ₃ BO ₃	0.02	1.5	22 Thiamine		0.1
11 CoCl ₂	0.01		23 Naphtheleneacetic acid	0.1	
12 CuSO ₄	0.01		24 Glycine		3
			25 Agar	12,000	6000

/1/ For callus tissues. /2/ For callus and tumor tissues.

192. SYNTHETIC CULTURE MEDIA: PLANTS

All values are mg of component per liter of culture media. Those for amino acids are for D-isomers.

Component	Value	Component	Value	Component	Value	Component	Value
Higher Plants		Fungi: Neurospora		Bacteria: Hemophilus parainfluenzae		Bacteria: L. leishmannii ¹⁰ (concluded)	
1 H ₃ BO ₃	2.86	58 NH ₄ NO ₃	1000	116 CaCl ₂	3	177 Phenylalanine	500
2 Ca(NO ₃) ₂ ·4H ₂ O	1680	59 (NH ₄) ₂ C ₄ H ₄ O ₆	5000	117 FeSO ₄ ·7H ₂ O	12.8	178 Proline	400
3 CuSO ₄ ·5H ₂ O	0.08	60 H ₃ BO ₃	0.06	118 MgSO ₄ ·7H ₂ O	82	179 Serine	100
4 FeSO ₄ ·7H ₂ O	5 ¹	61 CaCl ₂	100	119 KH ₂ PO ₄	3120	180 Threonine	100
5 MgSO ₄ ·7H ₂ O	493	62 CuSO ₄ ·5H ₂ O	0.40	120 Glucose	1000	181 Tryptophane	50
6 MnCl ₂ ·4H ₂ O	1.8	63 FeSO ₄ ·7H ₂ O	0.72	121 Glutamic acid	2000	182 Tyrosine	400
7 H ₂ MoO ₄ ·H ₂ O	0.02	64 MgSO ₄ ·7H ₂ O	500	122 d-Biotin	0.001	183 Valine	200
8 KNO ₃	505	65 MnCl ₂ ·4H ₂ O	0.07	123 Thiamine·HCl	1	184 Folic acid	0.06
9 KH ₂ PO ₄	136	66 KH ₂ PO ₄	1000	124 Alanine	1000	185 Niacin	1
10 ZnSO ₄ ·7H ₂ O	0.22	67 NaCl	100	125 Arginine·HCl	400	186 α-Ca-pantothenate	1
Algae: Chlorella ²		68 Na ₂ MoO ₄	0.04	126 Aspartic acid	1000	187 Para-aminobenzoic acid	0.04
11 NH ₄ VO ₃	0.02	69 ZnSO ₄ ·7H ₂ O	8.8	127 Cystine	200	188 Pyridoxine·HCl	2
12 H ₃ BO ₃	2.86	70 Sucrose	15,000	128 Glycine	100	189 Pyridoxamine·HCl	0.4
13 CaCl ₂	55 ³	71 d-Biotin	0.005	129 Histidine·HCl	200	190 Riboflavin	1
14 Co(NO ₃) ₂ ·6H ₂ O	0.05 ³	Bacteria: Photosynthetic		130 Isoleucine	200	191 Adenine sulfate	5
15 CuSO ₄ ·5H ₂ O	0.08	72 NH ₄ Cl	1000	131 Leucine	200	192 Guanine·HCl	5
16 FeSO ₄ ·7H ₂ O	20	73 H ₃ BO ₃	2.8	132 Lysine·HCl	400	193 Uracil	5
17 MgSO ₄ ·7H ₂ O	250	74 CaCl ₂	100	133 Methionine	200	194 Xanthine	8
18 MnCl ₂ ·4H ₂ O	1.8	75 Co(NO ₃) ₂ ·6H ₂ O	0.05	134 Phenylalanine	200	195 Na acetate	3600
19 KNO ₃	2000	76 CuSO ₄ ·5H ₂ O	0.02	135 Proline	200	196 Tween 80	1
20 K ₂ HPO ₄	1740	77 FeSO ₄ ·7H ₂ O	20	136 Serine	200	Bacteria: Streptococcus faecalis	
21 KH ₂ PO ₄	1360	78 MgSO ₄ ·7H ₂ O	250	137 Threonine	200	197 NH ₄ Cl	2500
22 Na ₂ MoO ₄	0.02	79 MnCl ₂ ·4H ₂ O	0.05	138 Tryptophan	200	198 FeSO ₄ ·7H ₂ O	27
23 ZnSO ₄ ·7H ₂ O	0.02	80 K ₂ HPO ₄	500	139 Tyrosine	200	199 MgSO ₄ ·7H ₂ O	512
24 Na citrate	200	81 NaCl	3000 ⁷	140 Valine	200	200 MnSO ₄	30
Algae: Blue-green		82 Na ₂ CO ₃	2000 ⁸	141 Choline·Cl	5	201 K ₂ HPO ₄	5000
25 NH ₄ VO ₃	0.02 ³	83 Na ₂ S	1000 ⁸	142 Folic acid	0.01	202 NaCl	15
26 H ₃ BO ₃	2.86	84 Na ₂ CO ₃	2000	143 l-Inositol	20	203 Na citrate	5000
27 CaCl ₂	55	85 ZnSO ₄ ·7H ₂ O	0.5	144 Niacin	0.5	204 Glucose	20,000
28 Co(NO ₃) ₂ ·6H ₂ O	0.05 ³	86 Glutamic acid	2000 ⁹	145 α-Ca-pantothenate	1	205 Glutamic acid	1000
29 CuSO ₄ ·5H ₂ O	0.08	87 d-Biotin	0.004 ⁹	146 Para-aminobenzoic acid	0.001	206 d-Biotin	0.01
30 FeSO ₄ ·7H ₂ O	20	88 Thiamine·HCl	1.0 ⁹	147 Pyridoxine·HCl	2	207 Thiamine·HCl	0.5
31 MgSO ₄ ·7H ₂ O	250	Bacteria: Bacillus subtilis		148 Riboflavin	0.1	208 Alanine	500
32 MnCl ₂ ·4H ₂ O	1.8	89 (NH ₄) ₂ HPO ₄	8000	149 Adenine sulfate	10	209 Arginine·HCl	400
33 KNO ₃	2000 ⁴	90 FeCl ₃ ·6H ₂ O	33	150 Guanine·HCl	10	210 Asparagine	500
34 K ₂ HPO ₄	2580	91 MgSO ₄ ·7H ₂ O	614	151 Uracil	10	211 Aspartic acid	500
35 NaCl	40	92 MnSO ₄	15	152 Coenzyme I	0.1	212 Cystine	200
36 Na ₂ CO ₃	1500 ⁵	93 KCl	400	153 Putrescine	500	213 Glycine	100
37 Na ₂ MoO ₄	0.2	94 NaCl	300	154 Na acetate	6000	214 Histidine·HCl	200
38 Na ₂ CO ₃	1500	95 Na ₂ SO ₄	4000	Bacteria: Lactobacillus leichmannii ¹⁰		215 Isoleucine	200
39 ZnSO ₄ ·7H ₂ O	0.02	96 ZnCl ₂	10	155 NH ₄ Cl	280	216 Leucine	200
40 Na citrate	200	97 Sucrose	100,000	156 FeSO ₄ ·7H ₂ O	10	217 Lysine·HCl	400
Fungi: Aspergilli and Penicillia		98 Glutamic acid	2000	157 MgSO ₄ ·7H ₂ O	1400	218 Methionine	200
41 FeSO ₄ ·7H ₂ O	10	99 d-Biotin	0.02	158 MnSO ₄	203	219 Phenylalanine	200
42 MgSO ₄ ·7H ₂ O	500	100 Thiamine·HCl	4	159 K ₂ HPO ₄	2000	220 Proline	400
43 KCl	500	101 Asparagine	2000	160 KH ₂ PO ₄	2000	221 Serine	500
44 K ₂ HPO ₄	1000	102 Choline·Cl	10	161 Na citrate	5000	222 Threonine	200
45 NaNO ₃	3000	103 Folic acid	0.02	162 Glucose	20,000	223 Tryptophane	200
46 Sucrose	30,000	104 l-Inositol	10	163 Glutamic acid	400	224 Tyrosine	200
Fungi: Basidiomycetes ⁶		105 Niacin	2	164 d-Biotin	0.005	225 Valine	200
47 (NH ₄) ₆ Mo ₇ O ₂₄ ·4H ₂ O	0.02	106 α-Ca pantothenate	4	165 Thiamine·HCl	1	226 Folic acid	0.02
48 H ₃ BO ₃	0.57	107 Para-aminobenzoic acid	0.02	166 Alanine	200	227 Niacin	1
49 CuSO ₄ ·5H ₂ O	0.04	108 Pyridoxine·HCl	2	167 Arginine·HCl	200	228 α-Ca-pantothenate	0.5
50 FeSO ₄ ·7H ₂ O	0.15	109 Pyridoxamine·HCl	2	168 Asparagine	200	229 Para-aminobenzoic acid	0.2
51 MgSO ₄ ·7H ₂ O	500	110 Riboflavin	4	169 Aspartic acid	200	230 Pyridoxine·HCl	0.5
52 MnCl ₂ ·4H ₂ O	0.04	111 Adenine sulfate	4	170 Cystine	400	231 Pyridoxamine·HCl	0.5
53 KH ₂ PO ₄	1500	112 Guanine·HCl	40	171 Glycine	300	232 Riboflavin	0.5
54 ZnSO ₄ ·7H ₂ O	0.31	113 Uracil	40	172 Histidine·HCl	200	233 Adenine sulfate	10
55 Glucose	10,000	114 Xanthine	40	173 Isoleucine	300	234 Uridine	0.2
56 Glutamic acid	1260	115 Citric acid	2000	174 Leucine	100	235 Glutathione	20
57 Thiamine·HCl	1			175 Lysine·HCl	600	236 Na acetate	5000
				176 Methionine	100	237 Tween 80	10

/1/ To be added twice weekly or as indicated by iron deficiency. /2/ And other simple green algae. /3/ Not yet shown to be generally required.

/4/ May be omitted for nitrogen-fixing forms. /5/ For those strains which grow only at an alkaline pH. /6/ Wood-rotting types. Biotin and/or ribo-

flavin may be required by some. /7/ For marine forms. /8/ For purple and green sulfur bacteria. /9/ For non-sulfur purple bacteria: additional

compounds not listed (mg/L): Na succinate, 4000; glycerol, 2000; malic acid, 3000; K acetate, 1000; niacin, 1.0. /10/ Additional components not

listed (mg/L): cysteine, 800; glutamine, 100; hydroxyproline, 50; norleucine, 200; cobalamin, 0.01; pyridoxal·HCl, 2; pyridoxal phosphate, 1;

cytidylic acid, 10; sodium ethyl oxalacetate, 100.

193. DILUENTS FOR CULTURE MEDIA: ANIMAL TISSUES

In general, these diluents are used only in combination with naturally occurring body substances (e.g., blood serum, tissue extracts) and/or more complex chemically defined feeding solutions, as presented in the next table. pH of the final medium must be regulated. Values are mg/liter.

Component	Tyrodé I 1910	Earle	Hanks	Component	Tyrodé I 1910	Earle	Hanks
1 NaCl	8000	6880	8000	6 NaHCO ₃	1000	2200	340
2 KCl	200	400	400	7 Na ₂ HPO ₄			60
3 CaCl ₂	200	200	140	8 NaH ₂ PO ₄ ·H ₂ O	58 ²	125	
4 MgCl ₂ ·6H ₂ O	214 ¹		100	9 KH ₂ PO ₄			60
5 MgSO ₄ ·7H ₂ O		200	100	10 Glucose	1000	1000	1000

/1/ Calculated from 100 mg/L MgCl₂ in original formula. /2/ Calculated from 50 mg/L NaH₂PO₄ in original formula.

194. CHEMICALLY DEFINED CULTURE MEDIUM: ANIMAL TISSUES

Data adapted from Healy, G. M., et al., Proc. Soc. Exp. Biol. & Med. 89:71, 1955.

Component	Value mg/L	Component	Value mg/L
1 L-Alanine	25	32 α-Tocopherol phosphate	0.01
2 L-Arginine	70	33 Cholesterol	0.2
3 L-Aspartic acid	30	34 Tween 80 (oleic acid)	5
4 L-Cysteine	260	35 Cocarboxylase (88% pure)	1
5 L-Cystine	20	36 Coenzyme A (75% pure)	2.5
6 L-Glutamic acid	75	37 Diphosphopyridine nucleotide (95% pure)	7
7 Glycine	50	38 Flavin adenine dinucleotide (60% pure)	1
8 L-Histidine	20	39 Glutathione	10
9 L-Hydroxyproline	10	40 Triphosphopyridine nucleotide (80% pure)	1
10 L-Isoleucine	20	41 Uridine triphosphate (90% pure)	1
11 L-Leucine	60	42 Adenine desoxyriboside	10
12 L-Lysine	70	43 Cytosine desoxyriboside	10
13 L-Methionine	15	44 Guanine desoxyriboside	10
14 L-Phenylalanine	25	45 5-Methyldeoxycytidine	0.1
15 L-Proline	40	46 Thymidine	10
16 L-Serine	25	47 Ethanol ¹	16
17 L-Threonine	30	48 D-Glucose	1000
18 L-Tryptophan	10	49 L-Glutamine	100
19 L-Tyrosine	40	50 Phenol red ²	20
20 L-Valine	25	51 Sodium acetate	50
21 Vitamin A	0.1	52 Sodium glucuronate	4.2
22 Ascorbic acid	50	53 NaCl	6800
23 Biotin	0.01	54 KCl	400
24 Calciferol	0.1	55 CaCl ₂	200
25 Choline	0.5	56 MgSO ₄ ·7H ₂ O	200
26 Folic acid	0.01	57 NaH ₂ PO ₄ ·H ₂ O	140
27 Inositol	0.05	58 NaHCO ₃	2200
28 Menadione	0.01	59 Fe(NO ₃) ₃	0.1
29 Para-aminobenzoic acid	0.05	60 n-Butyl parahydroxybenzoate	0.2
30 Pyridoxal	0.025	61 Dihydrostreptomycin sulfate	100
31 Pyridoxine	0.025	62 Sodium penicillin G	1

/1/ As an initial solvent for fat-soluble constituents. /2/ pH indicator.

195. CULTURE MEDIA: SELECTED PROTOZOA

Part I: PARASITIC AMEBAE

In presence of bacterial flora derived from intestinal tract of host.

In presence of bacterial flora derived from intestinal tract of man.		Species Showing Growth ¹	
Medium	Diphasic		
	<div>Solid Phase</div> <div>Liquid Phase</div>		
1	Slant of coagulated whole egg ² with or without rice starch, rice flour or powder ³	Ringer's or Locke's solution, or 0.85% NaCl with serum or liquid egg white overlay ⁴	Dientamoeba fragilis, Entamoeba aulostomi, E. coli, E. gingivalis, E. histolytica, Endolimax nana
2	Same as 1 above	Same as 1 above, plus liver extract	Entamoeba coli, E. histolytica
3	Same as 1 above	No enrichment	D. fragilis, E. coli, E. histolytica, E. invadens, E. terrapini
4	Slant of coagulated serum	Same as 1 above	D. fragilis, E. coli, E. histolytica, Endolimax nana
5	Slant of liver infusion agar	Same as 1 above	Entamoeba coli, E. histolytica, E. invadens, E. terrapini
	Monophasic		
6	Same as liquid phase of 1 above, plus rice starch ⁵		E. barreti, E. histolytica, E. invadens, E. ranarum, E. terrapini, E. thomsoni
7	Bacto-beef heart infusion, plus rice starch		E. histolytica, Iodamoeba buetschlii
8	Egg infusion with or without liver extract, blood clot extract, etc., with rice starch		D. fragilis, E. coli, E. histolytica, Endolimax nana
9	Alcoholic extract of egg yolk, and/or certain tissues, with rice starch		Entamoeba histolytica

/1/ Entamoeba aulostomi, E. coli, E. gingivalis, E. histolytica, Endolimax nana and Iodamoeba buetschlii cultivated at 37°C, transferred at 48 to 72 hr intervals; others cultivated at 25°C or lower and transferred less frequently. /2/ From 3 to 5 ml of egg emulsion, tubed, slanted, inspissated, and sterilized. /3/ Several mg per tube, sterilized by dry heat and added separately. /4/ Exact formulae unimportant; from 5 to 12.5% of enrichment is used. /5/ Only serum enrichment has been reported, from 5 to 12.5%; rice starch not always used.

Part II: ENTAMOEBA HISTOLYTICA

Medium		Microbial Associate	
Diphasic		Monoxenic ¹ Culture	
Solid Phase	Liquid Phase	Actinomyces muris, Aerobacter aerogenes, Aplanobacter stewartii, Bacillus mesentericus, B. subtilis, Bacterium coronofaciens, Clostridium perfringens ² , Escherichia coli, Klebsiella pneumoniae, Neisseria catarrhalls, organism t ^{6,7} , Proteus rettgeri, Salmonella paratyphi, S. schottmuelleri, S. typhosa, Serratia marcescens, Shigella ambigua, S. dysenteriae, S. paradysenteriae, S. sonnei, Staphylococcus albus, S. aureus, Streptococcus fecalis, S. hemolyticus, S. viridans, S. zymogenes	
1 Slant of coagulated whole egg ² with rice starch or flour ³	Locke's solution with or without serum ⁴		
2 Slant of coagulated egg-white with rice flour ³	Locke's solution with cholesterol, with or without B vitamins	Aerobacter aerogenes (n), Escherichia coli (n), organism t (w) ⁶	

/1/ Only one of the microbial associates or symbionts listed is required, in conjunction with the respective medium, to permit growth of the ameba.

/2/ From 3 to 5 ml of egg emulsion, tubed, slanted, inspissated, and sterilized. /3/ Several mg per tube, sterilized by dry heat and added separately. /4/ Exact formulae unimportant; from 5 to 12.5% of enrichment is used. /5/ Dientamoeba fragilis also grows in this medium (Line 1) in the presence of C. perfringens. /6/ Probably a species of Clostridium. /7/ Entamoeba coli also grows in this medium (Line 1) in the presence of organism t.

195. CULTURE MEDIA: SELECTED PROTOZOA (Concluded)
Part II: ENTAMOEBA HISTOLYTICA (Concluded)

Medium		Microbial Associate
Diphasic (concluded)		
3	Slant of liver infusion agar with rice starch or flour	0.85% NaCl 9 parts, serum 1 part
Monophasic		
4	Egg yolk infusion with rice flour	
5	0.85% NaCl 9 parts, serum 1 part, with rice starch, and methylene blue as indicator	
6	Thioglycollate medium (BBL) with serum, trypticase medium (BBL) with serum	
7	Proteose peptone, with liver extract, L-cystine, methionine, cholesterol, and rice flour, in balanced salt solution	
8	Twelve amino acids, B vitamins, nucleic acid, cholesterol, rice flour, in balanced salt solution	
9	Same as 8 above, with 20 amino acids	
Axenic ¹¹ Culture		
10	Whole egg medium with heat-killed bacteria and rice flour	
11	Mixed chick embryo cells, serum, in balanced salt solution	
12	Proteose peptone with glucose	
13	Proteose peptone without glucose	

Bacillus brevis, B. circulans, B. mesentericus, B. subtilis, Clostridium botulinum, C. pasteurianum, C. perfringens, C. tetani, Escherichia coli, Neisseria catarrhalis, Paracolobactrum coliforme, Staphylococcus albus, S. aureus, Vibrio comma

Aerobacter aerogenes, A. cloacae, Kurthia zenkeri, Proteus vulgaris, Streptococcus equinus, S. fecalis, S. liquefaciens

Escherichia coli

Streptobacillus⁹ (generic and specific identification not determined), Trypanosoma cruzi¹⁰

Organism t⁶

Organism t⁶

Organism t⁶

Entamoeba histolytica¹² grows in this medium without microbial associate or symbiont

E. invadens and E. histolytica¹³

Mayorella pasteurensis

Acanthamoeba castellanii

11/ Only one of the microbial associates or symbionts listed is required, in conjunction with the respective medium, to permit growth of the amebae. 16/ Probably a species of Clostridium. 18/ BBL: A Baltimore Biological Laboratories product. 19/ The streptobacillus is grown separately under a petroleum seal; amebae and dosage of penicillin are added. 10/ T. cruzi is grown separately and amebae added. 11/ No microbial associate or symbiont required, in conjunction with the respective medium, to permit growth of the amebae. 12/ Indefinite serial transfer not attained. 13/ E. histolytica requires anaerobiosis in H₂ or N₂ with 5% CO₂.

Part III: TRYPANOSOMATIDAE
Culture in absence of commensal organisms (axenic culture).

Medium ^{1, 2}		Species ³ Showing Growth
Solid Phase		
1	15.6 g agar, 7 g NaCl, 330 ml defibrinated rabbit blood	
2	50 g bacto beef, 25 g bacto peptone, 7 g NaCl, 10 g bacto agar, 50 ml 1% glucose solution, 50 ml defibrinated guinea pig blood	
3	50 g bacto beef, 20 g neopeptone, 5 g NaCl, 20 g bacto agar, 100 or 300 ml defibrinated rabbit blood	
4	3 g bacto beef, 5 g bacto peptone, 8 g NaCl, 15 g bacto agar, 330 ml citrated human or rabbit blood	
Liquid Phase ⁴		
1	Water of condensation	
2	Equal parts of peptone broth and dextrose solution	
3	Locke's solution	
4	Locke's solution	
Solid		
5	10-15 g agar, 10 g glucose, 100 ml horse meat broth, 1 L horse meat broth, 1 L defibrinated horse blood	
6	50 g bacto beef, 20 g neopeptone, 5 g NaCl, 20 g nobel agar, 100 ml defibrinated human or rabbit blood	
7	31 g nutrient agar, 165 ml human citrated, inactivated plasma, 165 ml human red cells	
Semi-solid ⁵		
8	1 part 3% agar, 8 parts Locke's solution with 0.2% glucose, 1 part rabbit serum	
9	3 g agar, 150 ml defibrinated rabbit blood, 100 ml normal saline	
Liquid		
10	0.5 ml human or monkey blood, 0.5 ml 2% sodium citrate in 0.85% NaCl solution, 1 ml Ringer's solution (with 0.6% NaCl)	
11	2-2.5 ml Ringer's solution (with 0.6% NaCl), or 2-2.5 ml Tyrode solution, 2 ml citrated (1%) human blood	
12	Overlay of 3 above for T. cruzi, or overlay of 4 above for T. gambiense and T. rhodesiense	
13	10 g peptone, 10 g "casamino acids," 5 g NaCl, 2 g glucose, 100 mg each of alanine and glycine, 20 mg each of folic acid, nicotinamide, thiamin and choline	
Synthetic		
14	Mixture of salts, metals, amino acids, vitamins, sorbitol, and hemin	
Dialysate		
15	Cellophane loop filled with Locke's solution suspended in tubes of 3	
Chick Embryo and Tissue Culture		
16	Chorio-allantoic membrane	
17	Blood or organs	
18	Tissue culture	

L. brasiliensis, L. donovani, L. tropica, T. cruzi, T. melophagium, T. theileri, T. rotatorium, avian trypanosomes: various spp³

T. cruzi

L. brasiliensis, L. donovani, L. tropica, T. conorhini, T. cruzi, T. lewisi, T. pipistrelli, T. rangeli

T. gambiense, T. rhodesiense

L. brasiliensis, L. donovani, L. tropica, T. cruzi, T. melophagium, T. theileri, avian trypanosomes³, T. rotatorium, Leptomonas ctenocephali, L. fasciculata

Leishmania tropica, T. cruzi

T. gambiense, T. rhodesiense

L. donovani, L. tropica, T. cruzi, Herpetomonas culicidarum

L. donovani, L. tropica

T. congolense, T. gambiense

T. congolense, T. gambiense

T. cruzi, T. gambiense, T. rhodesiense

T. cruzi

H. culicidarum

T. cruzi

L. donovani, L. tropica, T. cruzi, T. gambiense

T. cruzi, T. equiperdum, T. evansi, T. gambiense, T. rhodesiense

L. donovani, T. cruzi

11/ Ingredients of solid phase media, Lines 1 to 4, and of media given on Lines 5-13 are in amounts to be added to 1 L distilled water unless otherwise specified; test tube cultures usually contain 5 ml base (Lines 1-4), flask or plate cultures (Lines 1-7) contain varying amounts of base depending on size of container. 12/ Lines 1-15: cultures grown on media are usually maintained at temperatures of approximately 22-25°C; Lines 16 and 17: at 25-35°C; Line 18: at 37-39°C. 13/ Mammalian trypanosomatidae: Leishmania brasiliensis, L. donovani, L. tropica, Trypanosoma conorhini, T. cruzi, T. duttoni, T. lewisi, T. melophagium, T. pipistrelli, T. theileri, T. rangeli, T. congolense, T. equiperdum, T. evansi, T. gambiense, T. rhodesiense; avian trypanosomatidae: various species, not named because of uncertain taxonomic status; frog trypanosomatidae: T. rotatorium; insect trypanosomatidae: Herpetomonas culicidarum, Leptomonas ctenocephali, L. fasciculata. 14/ Lines 2 and 3: receive 2 to 3 ml overlay, flask cultures approximately 15 ml. 15/ Lines 8-14: varying amounts are used depending upon size of container.

196. FACTORS AFFECTING NUTRIENT REQUIREMENTS: MAN

The daily requirement of a nutrient may be altered -- either increased or decreased -- by a change in the daily intake of some other nutrient or by changes in other existing conditions of health or disease. The actual minimum requirement of many of the nutrients is as yet undetermined for man. Factors affecting the requirement are not available for "essential" fatty acids, vitamin E, inositol, pantothenic acid, para-aminobenzoic acid, chlorine, cobalt, copper, magnesium, manganese, and silicon.

Part I: FACTORS INFLUENCING BIOLOGICAL AVAILABILITY OF NUTRIENTS

Increase		Decrease	
Energy: Total Calories		Vitamin K (concluded)	
1		29	Defective absorption. (See Item 15 (b), (c), (f).)
	Decreased absorption, increased loss from the body, or defective utilization of protein, carbohydrate and fats. (See Items 2 to 14.)	30	Inadequate intestinal flora in newborn infants.
	Protein	31	Defective utilization in advanced liver disease.
2	Adequate energy production from carbohydrate and fat.		Niacin
	Inadequate energy production from carbohydrate and fat: (a) low intake; (b) diabetes mellitus.	32	Oral antibiotics.
3	Proper amino acid balance in ingested protein.	33	Decreased absorption caused by disease of the gastrointestinal tract.
	Amino acid deficiency or imbalance in ingested protein.	34	Decreased formation from tryptophan in vitamin B ₆ deficiency.
4	Anabolic hormones; growth hormones.		Pyridoxine Group (Vitamin B ₆)
	Anti-anabolic hormones; adrenal cortical hormones.	35	Loss in urine caused by isonicotinic acid hydrazide therapy.
5			Riboflavin
	Excessive heat or chemical treatment of protein.	36	Decreased absorption caused by disease of the gastrointestinal tract.
6		37	Increased excretion in association with protein breakdown.
	Defective absorption caused by: (a) deficiency of digestive enzymes; (b) diarrhea; (c) intestinal parasites; (d) disease of the gastrointestinal tract.		Thiamine
7		38	Decreased absorption caused by: (a) thiaminase in raw fish; (b) administration of live yeast and alkali; (c) low gastric acidity; (d) gastrointestinal diseases.
	Loss of protein in: (a) urine; (b) exudates; (c) transudates; (d) hemorrhage.	39	Loss caused by diuresis.
8			Calcium
	Loss of nitrogen from tissues in: (a) caloric deficiency; (b) burns; (c) trauma; (d) surgery.	40	High dietary acidity. Decreased absorption caused by: (a) low gastric acidity; (b) low dietary acidity; (c) phytic, oxalic, or benzoic acids in diet; (d) phosphorus in diet; (e) fatty acids in diet; (f) impaired fat absorption (caused by deficiency of bile salts, pancreatic disease, sprue syndrome, celiac disease, and idiopathic steatorrhea).
	Carbohydrate		Increased loss of calcium caused by: (a) bed rest, immobilization; (b) anti-anabolic hormones; (c) primary and secondary hyperparathyroidism; (d) renal rickets.
9		41	
	Decreased absorption caused by: (a) gastrointestinal diseases; (b) sprue; (c) hypoadrenalism; (d) hypothyroidism (e) panhypopituitarism.	42	Protein in diet.
10		43	Lactose in diet.
	Increased loss: glycosuria.	44	Citrates in diet.
11	Increased gluconeogenesis.	45	Vitamin D.
	Impaired gluconeogenesis.	46	Anabolic hormones.
12			Iron
	Diabetes mellitus.	47	Absorption increased by: (a) protein in diet; (b) ascorbic acid; (c) iron deficiency; (d) hemochromatosis.
	Fat		Absorption decreased by: (a) low gastric acidity; (b) phytate in diet; (c) phosphate in diet.
13	Increased absorption caused by emulsifying agents.		Utilization decreased by infections. ¹
	Poor absorption caused by: (a) deficiency of fat-splitting enzymes; (b) deficiency of bile salts; (c) sprue, celiac disease and idiopathic steatorrhea.	48	
14		49	Increased urinary excretion in nephrosis.
	Loss from body caused by: (a) chyluria; (b) chylous transudates.		Phosphorus
	Vitamin A and Precursors	50	Vitamin D. Decreased absorption caused by: (a) phytate in diet; (b) excess calcium in diet; (c) administration of aluminum.
15	Increased absorption caused by: (a) ready release of food carotene; (b) emulsifying agents.	51	Increased excretion of phosphorus caused by: (a) alkalosis; (b) bone injury; (c) hyperparathyroidism; (d) immobilization.
	Decreased absorption caused by: (a) food carotene not readily released; (b) deficiency of bile salts; (c) defective absorption of fat in sprue, celiac disease, idiopathic steatorrhea, and deficiency of fat-splitting enzymes; (d) ingestion of mineral oil; (e) destruction of vitamin A in gastrointestinal tract by oxidizing agents (rancid fat, ferric iron); (f) low dietary fat.		Potassium
16		52	Retention of potassium caused by: (a) anuria; (b) adrenal insufficiency.
	Defective storage in liver disease (?).		Loss of potassium caused by: (a) metabolic alkalosis and acidosis; (b) administration of ACTH and adrenal cortical hormones; (c) negative nitrogen balance; (d) diarrhea; (e) recovery phase following acute renal failure.
17			Sodium
	Defective conversion of carotene to vitamin A: (a) diabetes; (b) hypothyroidism.	53	Retention of sodium caused by: (a) administration of ACTH and adrenal cortical hormones; (b) hyperadrenalism; (c) hyperpituitarism.
	Ascorbic Acid		Excessive loss in sweat caused by: (a) high environmental temperature; (b) fever.
18			
	Gastric achlorhydria.		
19			
	Administration of alkali.		
20			
	Destruction during preparation or storage of food: (a) high temperature; (b) alkali; (c) copper; (d) iron.		
21			
	Increased loss in urine caused by certain drugs.		
	Biotin		
22			
	Raw egg white in diet.		
23			
	Oral antibiotics.		
	Choline		
24	Oral antibiotics.		
	Cobalamin (Vitamin B ₁₂)		
25			
	Poor absorption caused by lack of intrinsic factor in gastric juice (pernicious anemia).		
	Vitamin D		
26			
	Decreased absorption. (See Item 15 (b), (c), and (f).)		
	Folic Acid Group (Folacin)		
27			
	Decreased absorption caused by gastrointestinal disease.		
	Vitamin K		
28	Synthesis by intestinal microorganisms.	54	Excessive loss in urine caused by: (a) adrenal insufficiency; (b) diuresis; (c) certain injuries and infections of the central nervous system.
	Oral antibiotics.	55	Excessive loss from gastrointestinal tract in diarrhea and vomiting.

¹/ Poor utilization cannot be corrected by iron administration.

196. FACTORS AFFECTING NUTRIENT REQUIREMENTS MAN (Concluded)

The daily requirement of a nutrient may be altered -- either increased or decreased -- by a change in the daily intake of some other nutrient or by changes in other existing conditions of health or disease. The actual minimum requirement of many of the nutrients is as yet undetermined for man. Factors affecting the requirement are not available for "essential" fatty acids, vitamin E, inositol, pantothenic acid, para-aminobenzoic acid, chlorine, cobalt, copper, magnesium, manganese, and silicon.

Part II: FACTORS INFLUENCING NUTRIENT REQUIREMENTS PER SE

Increase		Decrease	
Energy: Total Calories		Vitamin K	
1 Growth.	Aging after maturity.	30 Pregnancy.	
2 Pregnancy and lactation.		31 Vitamin K deficiency: (a) hemorrhagic disease of newborn; (b) obstructive jaundice; (c) hypoprothrombinemia caused by oral antibiotics.	
3 Large body size.	Small body size.	Niacin	
4 Physical activity.	Physical inactivity.	32 Large body size.	Small body size.
5 Cold climate; exposure to cold.	Tropical climate.	33 Increased caloric requirement.	Decreased caloric requirement.
6 Hypermetabolic states, such as: (a) fever; (b) hyperthyroidism; (c) leukemia; (d) acromegaly; (e) hyperadrenalism; (f) induced by certain drugs.	Hypometabolic states, such as: (a) hypothyroidism; (b) panhypopituitarism; (c) hypoadrenalism.	34 Hypermetabolic states. (See Item 6.)	Hypometabolic states. (See Item 6.)
Protein		35 Niacin deficiency: pellagra.	High tryptophan intake.
7 Growth.		Pyridoxine Group (Vitamin B ₆)	
8 Pregnancy and lactation.		36 Pregnancy.	
9 Large body size.	Small body size.	37 Pyridoxine deficiency (primary and secondary).	
10 Hypermetabolic states. (See Item 6.)	Hypometabolic states. (See Item 6.)	Riboflavin	
11 Protein deficiency syndromes: (a) Kwashiorkor; (b) starvation; (c) simple protein depletion, primary or secondary. (See Part I, Items 2 to 8.)		38 Growth.	
Carbohydrate		39 Pregnancy and lactation.	
12 Hyperinsulinism.		40 Increased caloric requirement.	Decreased caloric requirement.
Vitamin A and Precursors		41 Hypermetabolic states. (See Item 6.)	Hypometabolic states. (See Item 6.)
13 Growth (e.g., bones, teeth). ¹		42 Riboflavin deficiency.	
14 Vitamin A deficiency syndromes: (a) night blindness; (b) xerophthalmia; (c) follicular hyperkeratosis.		Thiamine	
Ascorbic Acid		43 Increased caloric requirement.	Decreased caloric requirement.
15 Pregnancy and lactation.		44 Hypermetabolic states. (See Item 6.)	Hypometabolic states. (See Item 6.)
16 Growth.		45 Increased proportion of calories derived from carbohydrate sources.	Increased proportion of calories derived from non-carbohydrate sources.
17 Metabolic stress: ¹ (a) infectious disease; (b) hypermetabolic states; (c) trauma, burns, surgery; (d) toxic reactions from certain drugs.		46 Thiamine deficiency: (a) beriberi; heart disease, neuropathy; (b) polyneuritis of chronic alcoholism and pernicious vomiting of pregnancy; (c) Wernicke's encephalopathy; (d) Korsakoff's psychosis; (e) delirium tremens.	
18 Tissue repair.		Calcium	
19 High intake of tyrosine and phenylalanine in premature infants.		47 Growth and dentition.	
20 Vitamin C deficiency: scurvy.		48 Pregnancy and lactation.	
Choline		49 Rickets and osteomalacia.	
21 Methyl group deficiency (fatty liver).	Methionine or methyl precursors in diet.	50 Calcium deficiency with or without tetany.	
Cobalamin (Vitamin B ₁₂)		Fluorine	
22 Cobalamin deficiency: (a) nutritional megaloblastic anemia; (b) pernicious anemia; (c) sprue (at times); (d) certain nutritional neuropathies.		51 Dental caries. ²	
Vitamin D		Iodine	
23 Inadequate exposure to ultraviolet radiation.	Exposure to ultraviolet radiation.	52 Iodine deficiency: endemic goiter.	
24 Growth and dentition.	High dietary calcium and phosphorus.	Iron	
25 Pregnancy and lactation.		53 Growth.	Menopause.
26 Vitamin D deficiency: (a) rickets; (b) osteomalacia.		54 Pregnancy and lactation.	
27 Hypoparathyroidism.		55 Blood loss: (a) physiological (menstruation); (b) pathological.	
Folic Acid Group (Folacin)		Phosphorus	
28 Pregnancy and lactation.		56 Growth.	
29 Folic acid deficiency: (a) sprue; (b) nutritional megaloblastic anemia; (c) megaloblastic anemia of infancy; (d) megaloblastic anemia of pregnancy.		57 Pregnancy and lactation.	
		58 Phosphorus deficiency caused by rickets.	
		Potassium	
		59 Potassium deficiency.	
		Sodium	
		60 Sodium deficiency.	

/1/ Available evidence suggests this but definite proof is lacking. /2/ Fluorine has not been demonstrated to be an essential nutrient, but in amounts of 1 ppm is useful in prevention of dental caries.

197. NUTRITIONAL CHARACTERISTICS OF CHEMICAL ELEMENTS: ANIMALS

The functions listed in the table require the specific elements noted. In addition, carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur are required for the functions of synthesis of structural proteins, carbohydrates, fats and other organic compounds, and for formation of end products of metabolism.

1	BROMINE <u>Ingestion and Absorption:</u> Traces in many foods. Probably completely absorbed from gastrointestinal tract. <u>Distribution:</u> Same as chloride in mammals. In Tyrian Purple (= brominated indigo) derived from viscera of marine gastropod (<i>Purpura aperta</i>); in dibromotyrosine in protein gorgonin, from coral (<i>Primnoa lepadifera</i>). <u>Function:</u> Not known.
2	CALCIUM <u>Ingestion and Absorption:</u> Almost entirely as salts of inorganic or organic acids. Partial absorption from gastrointestinal tract. Absorption aided by vitamin D and low pH. <u>Distribution:</u> Insoluble calcium phosphate complex in bones, teeth in vertebrates. In exoskeleton of numerous invertebrates as calcium carbonate. Minute concentrations as soluble salts in body fluids, all species. As calcium carbonate in shell of certain eggs. <u>Function:</u> Component of supporting structure in higher forms, many lower forms. Vital electrolyte of cell and extracellular fluid. Protective shell of eggs.
3	CHLORINE <u>Ingestion and Absorption:</u> Ingested principally as NaCl (see SODIUM, below). <u>Distribution:</u> Distribution similar to that of sodium but, in general, milliequivalent concentrations are lower. Chief anion of gastric juice. Also present in all other gastrointestinal secretions and extracellular fluids. <u>Function:</u> Although principal anion of extracellular fluid, function is unknown. Variation in Cl concentration appears to be better tolerated than in Na and most other electrolytes.
4	COBALT <u>Ingestion and Absorption:</u> Trace constituent of many foods. Absorbed from gastrointestinal tract. <u>Distribution:</u> Trace distribution in many tissues, particularly glands and visceral organs, e.g., liver. <u>Function:</u> Component of vitamin B ₁₂ (cobalamin), required by some species from lowest to highest forms. Cobalt deficiency occurs in ruminants as "Pine" disease, salt sickness, bush sickness, "coast" disease. Cobalt enhances activity of certain peptidases.
5	COPPER <u>Ingestion and Absorption:</u> Minute amounts in food as copper protein complexes. Poorly absorbed from intestine. <u>Distribution:</u> Higher concentrations in invertebrates than in vertebrates. Highest concentrations in hepatopancreas and gonads of Mollusca; lowest concentration in muscle. High concentration in gut of insects. Present in turacin (red pigment of feathers of turaco bird). Injected Cu accumulates in liver, kidney. Liver is principal site of storage. <u>Function:</u> Erythropoiesis. Myelination of central nervous system. Maintenance of mammalian pigmentation. Trace quantities essential for hemoglobin and possibly iron-porphyrin-protein enzyme synthesis. Constituent of several enzymes present in animal tissues (polyphenol oxidase, tyrosinase, laccase, catechol oxidase, and ascorbic acid oxidase). Component of hemocyanin, respiratory pigment of numerous marine animals; component of hepatocuprein, hemocuprein-protein complexes found in liver, blood of certain mammals. Nutritional deficiency disease occurs in cattle, sheep, with inadequate intake or with increased intakes of molybdenum. Molybdenum and copper are mutually antagonistic in ruminant metabolism.
6	FLUORINE <u>Ingestion and Absorption:</u> Traces in various foods, significant quantities in water in certain areas. <u>Distribution:</u> Present in bones, teeth. High concentration of 0.6-1.6% F in bones of sea animals. <u>Function:</u> Decreases incidence and severity of dental caries.
7	IODINE <u>Ingestion and Absorption:</u> Trace amounts in various foods mostly as iodide or as component of organic compounds. Amount in food related to iodine content of soil. Absorbed from intestine and, in lower forms, through cell membranes. <u>Distribution:</u> Principally in thyroid of vertebrates. Component of thyroxine, diiodotyrosine and thyroglobulin. Trace amounts in other tissues. Relatively more iodine in marine fish and other marine animals. <u>Function:</u> Minute intake essential for growth and for prevention of goiter.
8	IRON <u>Ingestion and Absorption:</u> Mainly as ferrous compounds from gastrointestinal tract. More absorption with iron deficiency states. <u>Distribution:</u> In blood hemoglobin, muscle hemoglobin, cytochrome of all cells. Stored in liver and spleen as ferritin (iron phosphoprotein). <u>Function:</u> Respiratory pigments of higher and lower forms. (Platyhelminthes contain hemoglobin.) Cytochrome is present in practically all cells.
9	MAGNESIUM <u>Ingestion and Absorption:</u> Widely distributed in foods. Ingested as salt of inorganic or organic acid. Absorbed from intestine. <u>Distribution:</u> Minute amounts in plasma and extracellular water. Large amounts in intracellular fluid. <u>Function:</u> Essential electrolyte. Low concentrations increase cell irritability. Required for activity of several animal enzymes.
10	MANGANESE <u>Ingestion and Absorption:</u> Traces present in most plant and animal foods. Poorly absorbed from gastrointestinal tract. <u>Distribution:</u> Particularly in liver, pancreas and hair. Also in all other tissues. Blood pigment of shellfish (<i>Pinna squamosa</i>) contains Mn rather than Fe or Cu. <u>Function:</u> Component of enzyme arginase. Enhances effect of certain proteinases. Necessary for growth of young animals (rabbits, rats). Also required for reproductive processes in many adult forms. Required for fertility of hen's eggs. Needed to prevent perosis in chicks.
11	PHOSPHORUS <u>Ingestion and Absorption:</u> Occurs as phosphate in most foods. Absorbed from gastrointestinal tract in higher forms. Absorbed through cell membranes in lower forms. <u>Distribution:</u> Large quantities as phosphate complex of calcium in bone of vertebrates. Component of phospholipids (nerve and other tissues), phosphocreatine or phosphoarginine (muscle); as inorganic PO ₄ in cell, extracellular fluid; as nucleoprotein in all tissues; and as adenosine triphosphate (ATP) in variety of cells of higher and lower species. Intracellular inorganic phosphate phosphorus low compared to that of phosphate esters. <u>Function:</u> Important structural component of bone. Component of high energy P compounds (ATP, phosphocreatine, phosphoarginine, acetyl phosphate). Combines with intermediates in carbohydrate metabolism. Buffer in urine. Constituent of nucleoprotein. Component of phospholipids (intermediates in lipid metabolism).
12	POTASSIUM <u>Ingestion and Absorption:</u> Ingested as inorganic salt in variety of foods. Absorbed from intestine. Absorbed through gills and cell membranes in many lower marine forms. <u>Distribution:</u> Principal cation of intracellular water. Small amount in extracellular water. <u>Function:</u> Essential cation of intracellular fluid.
13	SILICON <u>Ingestion and Absorption:</u> Absorbed from intestine. Inhaled particles deposit in lungs and give rise to serious effects. Absorbed through cell membrane of lower forms. <u>Distribution:</u> In skeletal structures and in supporting structures of certain Protozoa, Porifera and higher forms. <u>Function:</u> Protective and structural component of various lower animals forms.
14	SODIUM <u>Ingestion and Absorption:</u> Widely distributed in foods as inorganic salt. More in foods of animal origin than in foods of plant origin. Taken as NaCl by many higher vertebrates including man. Absorbed from intestine in higher forms and through gills and cell membranes in lower forms. <u>Distribution:</u> Major part of body sodium is extracellular, much in bone. Some intracellular. Tissues vary in concentration of intracellular sodium, muscle containing only small amounts. Data on other than mammalian forms not available. <u>Function:</u> Chief cation of extracellular water. Essential for proper external environment of cells. Chief cation of intestinal secretions. Salts are important buffers of plasma, extracellular water and urine.
15	SULFUR <u>Ingestion and Absorption:</u> As inorganic sulfates, organic sulfates and sulphydryl sulfur of cystine and methionine. <u>Distribution:</u> Small amount of sulfate in extracellular H ₂ O. Relatively large amount in proteins and small amount in certain lipids. <u>Function:</u> Essential component of many proteins. Sulfuric acid secreted as digestive fluid in Ascidia. Sulfate is important anion in intracellular fluid. Sulfate used in detoxification reactions.
16	VANADIUM <u>Ingestion and Absorption:</u> Extracted from marine muds by Ascidia. <u>Distribution:</u> In blood respiratory pigment of marine worm, Ascidia. <u>Function:</u> Component of respiratory pigment which provides oxygen transport in Ascidia.
17	ZINC <u>Ingestion and Absorption:</u> Traces present in most foods. Absorbed from gastrointestinal tracts; in lower forms through cell membrane. <u>Distribution:</u> Largest quantities in pancreas, hair, nails, bone. Very large concentrations in certain oysters and herring. <u>Function:</u> Prosthetic group of carbonic anhydrase. Indispensable for nutrition of growing rat. Also required by adult for reproduction. Needed for activation of certain proteinases.

198. NUTRITIONAL CHARACTERISTICS OF CHEMICAL ELEMENTS: HIGHER PLANTS

Element	Occurrence and/or Function	Symptoms of Deficiency ²	Symptoms of Excess ²
1 B	Inverse relationship between boron level and water permeability of membranes and moisture content of tissues. (May be a constituent of cytoplasmic membranes). Necessary for cell division, and translocation of sucrose and possibly other sugars.	Terminal leaves necrotic, shed prematurely; internodes of terminal shoots shortened, usually rosetting; apical meristems blacken and die, general breakdown of meristematic tissue; roots short, stubby. Plants dwarfed, stunted. Flower development and seed production usually impaired or lacking.	Marginal necrosis in lower leaves, remainder of leaves dark green; death of most plants if present in considerable concentration.
2 Ca	Precipitates organic acids. Calcium pectate may be a constituent of the middle lamella. ³	Leaves chlorotic, rolled, curled; breakdown of meristematic tissues in stems and roots, in acute cases death; roots poorly developed, lack fiber, may appear gelatinous. Symptoms appear near growing points of stems and roots. Little or no fruiting.	Chlorosis similar to iron or manganese deficiency. ⁴ Zinc and boron deficiency may be induced when soil reaction, e. g., pH, is high.
3 Cu	Associated with tyrosinase, a polyphenoloxidase involved in reduction of molecular oxygen. In ascorbic acid oxidase, which may be concerned in respiratory oxidation. ⁵ In laccase. ⁶	Wilt of terminal shoots, often followed by death; leaf color often faded; carotene formation and pigmentation reduced.	Chlorosis similar to iron deficiency, followed by necrosis; permanent wilting of upper leaves; leaves may become wrinkled and necrotic at margins; fibrous roots stubby, poorly developed, brownish at tips; reduced growth; extreme cases death.
4 Fe	Associated with peroxidase, which breaks down peroxides and transfers active oxygen to oxidizable substances. In cytochrome oxidase, which plays a role in reduction of molecular oxygen. ⁵ In catalase, which effects the release of molecular oxygen from hydrogen peroxide.	Interveneal white chlorosis, appearing first on young leaves; tendency for chlorosis of all aerial parts, often becoming necrotic; in some cases leaves may be completely bleached, margins and tips scorched. Usually has an overall effect.	
5 Mg	In chlorophyll, which is essential for photosynthesis. Associated with co-carboxylase, which is the co-enzyme for the carboxylases; in enolase, which is necessary in glycolysis (from 2-phosphoglyceric acid to 2-phosphopyruvic acid); in hexokinase, which brings about transphosphorylation of glucose. Magnesium pectate may be a constituent of the middle lamella. ³	Mottled chlorosis with veins green, leaf web tissue yellow or white, appearing first on old leaves; severely affected leaves may wilt and shed, or may abscise without the wilting stage; brittleness of leaves common, necrosis often occurs.	Usually on interveneal necrosis.
6 Mn	Associated with arginase (?), which converts arginine to urea. In an unidentified enzyme, which brings about catabolism of oxaloacetic acid to pyruvic acid and carbon dioxide in respiration.	Mottled chlorosis with veins green and leaf web tissue yellow or white, appearing first on young leaves, may spread to old leaves; stems yellowish green, often hard and woody. Carotene development reduced.	Leaves pale, necrotic, bronzing at margins; similar to iron deficiency. With potato, small black spots on stem.
7 Mo	Associated with an unidentified enzyme (?), which is apparently required in ascorbic acid synthesis. Appears to effect the reduction of nitrate to ammonia. ⁷	Light yellow chlorosis of leaves; leaf blade may fail to expand.	Lower leaves yellow with brown necrotic areas; in severe cases, upper leaves may be stunted, chlorotic and abscise.
8 N	In proteins, the chief organic constituents of protoplasm. In chlorophyll, which is essential for photosynthesis. Important in the assimilation of sugars. In many organic compounds.	In young plants stunted growth and yellowish green leaves; older leaves light green, followed by yellowing and drying or shedding, often abundant anthocyanins in veins; shoots short, thin, growth upright and spindly; flowering reduced; with apple and peach, fruit highly colored develop slowly, small when mature. Appears first on older leaves, but usually has an overall effect.	Leaves dark green, excessive vegetative growth; high transpiration; reduced yield of seed and fruit crops; may secure satisfactory yield of leafy vegetables of reduced quality.
9 P	In phospholipids, e. g., lecithin, which are constituents of cytoplasmic membranes. In nucleoprotein, a constituent of the nucleus and chromosomes. In adenosine di- and triphosphates, which are required for phosphorylation reactions, glycolysis and synthesis of sucrose, starch and proteins. Di- and triphosphopyridine nucleotide, coenzymes which accept and/or donate hydrogen in oxidation-reduction reactions.	Young plants stunted, leaves dark blue-green, sometimes purplish (with potato and certain other vegetables, leaves pale green); stems slender; often anthocyanins in veins, may become necrotic; with potato, meristematic growth ceases; fruits ripen slowly; plants often dwarfed at maturity.	
10 K	May be involved in action of fructokinase and other enzyme systems. Facilitates carbohydrate synthesis and translocation of carbohydrates.	Leaves of potato usually dark blue-green and leaves of monocotyledons pale green or streaked with yellow, with marginal chlorosis and necrosis, appearing first on old leaves; usually wrinkled, corrugated or crinkled between veins.	Leaves yellowish green; reduced growth; tendency toward calcium and magnesium deficiency.
11 S	In cystine and cysteine, which are present in all plant proteins. In glutathione, which may function as a hydrogen carrier in respiration. In mustard oil glycosides, which may tie up reserve food substances which would otherwise be toxic to cells.	Leaves light green to yellow, appearing first along veins of young leaves; stems often slender.	Necrosis or firing of older leaves of certain species or varieties.
12 Zn	Associated with an unidentified enzyme, which is directly necessary for synthesis of tryptophan, the precursor of indoleacetic acid.	Leaves chlorotic and necrotic, appearing first on young growth; rosetting; premature shedding; whitish chlorotic streaks between veins in older leaves and whitening of upper leaves in monocotyledons; chlorosis of lower leaves in dicotyledons.	Leaves yellow from zinc-induced iron chlorosis.

/1/ Carbon, hydrogen and oxygen have been intentionally omitted from table. These elements are constituents of carbohydrates, fats, proteins, vitamins, hormones, chlorophyll and other organic compounds occurring in plants. The bicarbonate ion is involved in ion absorption or exchange. Oxygen is the final receptor of hydrogen in aerobic respiration. Many of the metallic elements (as ions) that are indicated as being associated with enzymes serve as activators for the enzyme. /2/ Data applicable primarily to herbaceous crop plants. /3/ The middle lamella is an intercellular layer flanked on each side by the primary cell walls. /4/ Chlorosis due to the physiological unavailability of iron and manganese or reduced potassium. /5/ Terminal step in aerobic respiration. /6/ The enzyme is of limited distribution in plants and its function is a matter of speculation. /7/ Nature of relationship undetermined.

199. NUTRITIONAL CHARACTERISTICS OF CHEMICAL ELEMENTS: BACTERIA AND FUNGI

The specific elements listed are either required or exert an effect on the associated functions. Carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur are required for the synthesis of structural proteins, carbohydrates, fats, and other organic compounds, and for formation of end-products of metabolism.

Species	Chemical Element	Occurrence and/or Function
Heterotrophic Bacteria¹		
1 <i>Aerobacter aerogenes</i>	Fe	Growth.
2	Mg, Mn	Associated with pyruvate → acetylmethylcarbinol.
3	Cr or Mn (partially replaceable by Al, Cu, Fe, Zn)	Fermentation.
4 <i>A. indologenes</i>	Fe	Associated with hydrogenase, formic dehydrogenase, formic hydrogenylase ² , and cytochrome.
5 <i>Azotobacter</i> spp	Fe	Growth.
6	Ca (replaceable by Sr); Mo (partially replaceable by V)	Nitrogen fixation.
7	Co, Mg, Mn, Zn	Associated with oxalacetate decarboxylase.
8 <i>Bacillus anthracis</i>	Ca, Fe, K, Mg, Mn	Growth.
9 <i>B. cereus</i>	K	Spore formation.
10 <i>B. subtilis</i>	Fe, K, Mg, Mn, Zn	Growth and production of subtilin (antibiotic).
11 <i>Brucella abortus</i>	Mg or Mn	Normal growth of antigenic non-smooth variants.
12 <i>B. suis</i>	Fe, Mg, Mn	Growth.
13 <i>Cellulomonas</i> spp	Mg	Growth.
14 <i>Clostridium acetobutylicum</i>	Fe	Fermentation.
15	Mn, Zn	Associated with phosphatase.
16	Mo (partially replaceable by V)	Nitrogen fixation.
17 <i>C. botulinum, C. histolyticus</i>	Fe	Associated with polypeptidase.
18 <i>C. butyricum</i>	Mo (partially replaceable by V)	Nitrogen fixation.
19 <i>C. perfringens</i>	Mg	Cell division.
20	Fe	Fermentation.
21 <i>Corynebacterium diphtheriae</i>	Fe	Growth and formation of toxin and porphyrin.
22 <i>Escherichia coli</i>	Fe	Growth.
23	Mg, Mn	Associated with pyruvic dehydrogenase and enolase.
24 <i>Hemophilus influenzae</i>	Fe	In growth factor, hemin.
25 <i>Klebsiella pneumoniae</i>	Fe	Growth.
26 <i>Lactobacillus arabinosus, L. casei</i>	K, Mn	Growth.
27 <i>L. lactis, L. leichmanii</i>	Co	In growth factor, vitamin B ₁₂ .
28 <i>Leuconostoc mesenteroides</i>	K, Mn, P	Growth.
29 <i>Propionibacterium jensenii</i>	Mg, Zn	Associated with phosphatase.
30 <i>Pseudomonas</i> spp	B, Ca, Co, Cu, Fe, Mn, Mo, Zn	Growth.
31 <i>P. aeruginosa</i>	Fe, S	Production of pyocyanine (antibiotic).
32	Mg, P, S	Production of fluorescent pigment.
33	Fe	Associated with cytochrome, cytochrome oxidase, catalase, & peroxidase.
34	Mg	Growth.
35 <i>Serratia marcescens</i>	Fe, Mg	Pigment formation.
36 <i>Sporocytophaga myxococcoides</i>	Fe, Mg	Growth and decomposition of cellulose.
37 <i>Streptococcus fecalis</i>	K, Mn, P	Growth.
38 <i>Streptomyces fradiae</i>	Fe, Zn	Production of neomycins.
39 <i>S. griseus</i>	Co	Production of vitamin B ₁₂ .
40	Fe, Cr, Zn, Co, Cu, Mn, Ni, Se	Production of streptomycins.
41	Fe, Zn	Production of grisein.
42 <i>S. lavendulae</i>	Fe, Zn	Production of streptothricin.
Photosynthetic Bacteria³		
43 All species	Mg	In bacteriochlorophyll.
44 Non-sulfur purple bacteria	H ₂ ⁴	Molecular hydrogen oxidized as source of energy.
45 Sulfur purple bacteria	S, as sulfide, sulfite, or thiosulfate	Indispensable reducing agent in photosynthesis.
46 Sulfur green bacteria	S, as sulfide or thiosulfate	Indispensable reducing agent in photosynthesis.
Chemoautotrophic Bacteria⁵		
47 Iron bacteria	Fe, Mn	Substrates, oxidized as source of energy.
48 Nitrifying bacteria	Cu	Nitrification (oxidation of ammonia and nitrite).
49 Ammonia-oxidizing nitrifiers	N, as ammonia	Indispensable substrate, oxidized as source of energy.
50 Nitrite-oxidizing nitrifiers	N, as nitrite	Indispensable substrate, oxidized as source of energy.
51 Sulfur-oxidizers, aerobic	S, as sulfide or thiosulfate	Substrate, oxidized as source of energy.
52 Thiobacillus spp	S, as sulfide or thiosulfate	Substrate, oxidized as source of energy.
53 Sulfate-reducer	N, as nitrate	Indispensable oxidizing agent.
54 Sporovibrio desulfuricans	S, as sulfate	Indispensable oxidizing agent.
55 Clostridium acetivum	H ₂	Molecular hydrogen oxidized as source of energy.
56	CO ₂	Employed as oxidizing agent.
57 Hydrogenomonas spp	H ₂	Molecular hydrogen oxidized as source of energy.
58 Methanobacterium omelianski	H ₂	Molecular hydrogen oxidized as source of energy.
59	CO ₂	Employed as oxidizing agent.
Fungi		
60 <i>Aspergillus fumigatus</i>	Fe, Zn	Production of gliotoxin and helvolic acid.
61 <i>A. niger</i>	Fe, Ni, Co, Al, Zn, Cr, Mn, Mo, Se, Pb, Cu, Ag, Te, U, Sb, W	Production of citric acid.
62	Fe	Production of gluconic acid.
63 <i>Aspergillus</i> sp	Fe, Zn	Production of citrinin.
64 <i>Candida guilliermondii, C. flareri</i>	Fe	Production of riboflavin.
65 <i>Penicillium citrinum</i>	Fe, Mn	Production of citrinin.
66 <i>P. notatum</i> (chrysogenum group)	Zn, Fe, Mn, Cr, Cu, Al, Sn	Production of penicillin.
67	Fe, Zn	Production of gluconic acid.
68 <i>P. patulum</i>	Mn, Fe, Cu	Production of patulin and gentisic acid.
69 <i>Rhizopus delemar</i>	Al	Production of amylase.
70 <i>R. nigricans</i>	Zn, Fe, Cu, Mn	Production of fumaric and lactic acids, and ethanol.

/1/ Utilize such organic materials as sugars, fatty acids, amino acids, and alcohols as sources of carbon and energy for growth. /2/ Not established as a separate and distinct enzyme. Considered by many investigators to be a mixture of formic acid dehydrogenase and other enzymes. /3/ Capable of growing with CO₂ as carbon source, by utilizing light energy. /4/ Also organic compounds, e.g., alcohols and acids. /5/ Capable of growing with CO₂ as carbon source and with energy derived from oxidation of inorganic materials. A few of these organisms grow only autotrophically, but most of them can develop either as heterotrophs or as autotrophs.

200. EFFECT OF CERTAIN SOIL FACTORS ON CHEMICAL ELEMENT DEFICIENCY AND EXCESS

The effects of soil pH and general soil characteristics on chemical element availability, uptake, or toxicity, is manifested by the appearance of deficiency or excess symptoms in the indicator organisms growing in the soil medium specified. Parenthetical expressions associated with pH values describe the pH-symptom relationship as follows: High = symptoms rarely occur outside the stated pH. Medium = symptoms occur most commonly within the stated pH. Low = symptoms occur at all pH values. For symptoms of deficiency and excess, see Table

Part I: FACTORS AFFECTING DEFICIENCY

Element	Soil pH	General Soil Characteristics	Indicator Organism	Element	Soil pH	General Soil Characteristics	Indicator Organism		
1	Al ¹	5.5-8.0 (High)	Any soil of pH indicated.	Hydrangea.	10	I	(Low)	Areas of calcareous rocks, river flats, alluvial soils. Inland areas.	Animals feeding on I-deficient plants.
2	B	<5.0; 7.5-8.5 (Medium to low)	Calcareous soils with high Ca:B ratio; on leached acid sandy soils low in organic matter, particularly under intensive cropping.	2	Fe	>7.0 (Medium to high)	Particularly on calcareous soils; may be induced on acid soils by high concentration of heavy metals or P.	Apple, pear, sugar beet, citrus; peach, plum, etc.; grapes, pineapple, raspberry, strawberry.	
3	Co	(Low)	Soils of high pH ² and low Co content. Localized areas only.	3	Mg	<5.0 (Low)	Coarse-textured acid sandy soils; may be induced by heavy application or high content of K and Ca.	Apple, sugar beet, cauliflower, cereals, citrus, corn, hops, kale, lettuce, oats, potato, tobacco, tomato, tung tree.	
4	Cu	<5.0; 7.6-8.5 (Medium to low)	Heath soils; peat; acid and calcareous sands and gravels.	4	Mg	>9.0 (Medium)	Alkali soils with high exchangeable -Na - percentage (>40%).	Alfalfa.	
5	Mn	6.5-8.0 (High)	Calcareous soils, muck and peat.	5	N	<5.5 (Low)	Particularly coarse-textured acid soils and soils with low organic matter content.	Non-legumes. Legumes at low pH (caused by molybdenum deficiency).	
6	Mo	4.5-6.5 (Medium)	Coarse-textured, leached acid soils, low molybdenum content.	6	P	<6.5; 7.5-8.2 (Medium to high)	Particularly acid soils; sands and certain calcareous and muck or peat soils.	Barley, beet, grasses, legumes, cotton, potato, swede, turnip.	
7	Na	<5.5 (Medium)	Sandy, leached, inland soils.	7	K	<5.5; >7.5 (Medium to low)	Sandy soils, particularly when leached; coarse-textured calcareous soils.	Beet, corn, tree and bush fruits, legumes, potato, tobacco, tomato, tung tree.	
8	Zn	<5.0; 7.6-8.5 (Medium to low)	Leached sands and gravels; muck and peat; calcareous soils.	8	S	<5.0 (Low)	Particularly on leached, eroded soils of areas remote from urban and industrial districts.	Cabbage, other brassicas, cotton, flax, legumes, tea.	
9	Ca	<5.0 (High) >9 (Medium)	Coarse-textured sandy soils; highly acid soils. Alkali soils with high exchangeable -Na - percentage (>40%).						

/1/ Data refer to the role of aluminum in producing blue pigments in hydrangea flower. /2/ Availability of the element decreases with increasing soil pH. /3/ Sodium promotes vigor of certain higher plants, particularly celery, beet, and other root crops.

Part II: FACTORS AFFECTING EXCESS

Element	Soil pH	General Soil Characteristics	Indicator Organism	Element	Soil pH	General Soil Characteristics	Indicator Organism	
1	Al	<5.5 (High) ¹	Any soil of pH indicated.	8	Zn	<5.0	See cobalt.	Sugar beet, cauliflower, tomato.
2	B	>8.5 (High)	Coarse-textured soil irrigated with B-rich water.	9	As	8.5 (Medium)	Soils with minerals containing As, or soils receiving continued As-sprays. Sandy soils low in Fe ₂ O ₃ .	Alfalfa, apricot, barley, oats, peach, tomato.
3	Co	<6.0	Acid soils with high concentration of heavy metals, particularly from industrial effluent.	10	Cl	6.5-8.0 (Medium) >8.5 (High)	Saline soils containing chlorides, or soils irrigated with water high in chlorides.	Avocado, citrus, stone-fruits, grape.
4	Cu	<6.0	See cobalt.	11	F	<6.0 (High)	Soils in areas of industrial pollution.	Barley, buckwheat, collards, tomato.
5	Mn	<5.5 (High)	Often in rather impervious mineral soils.	12	Li	>8.2	Certain irrigated soils.	Citrus, corn, tomato, wheat.
6	Mo	>8.5 (High)	Soils derived from rocks high in molybdenum content, or receiving phosphate high in molybdenum.	13	Ni	<6 ²	Soils in areas of industrial pollution.	Beet, cabbage, clover, kale, oats, potato, tomato, turnip.
7	Na	>8.5 (High)	Alkali soils with exchangeable - Na - percentage (>15%). Saline soils or soils irrigated with water high in Na.	14	Se		Soils derived from Upper Cretaceous rocks and Upper Carboniferous limestone. Non-ferruginous soils in arid and semi-arid regions.	Animals feeding on Se-rich plants.

/1/ May occur with P deficiency. /2/ Inconsistent results with field plants.

201. EFFECT OF pH ON MACRONUTRIENT ABSORPTION: PLANTS

Plants were grown at pH 5-6 for 5 weeks in a dilute nutrient solution. At the end of this period they were placed for 3 days in a second solution containing (mEq per liter of solution): KNO_3 , 5; MgSO_4 , 2; KH_2PO_4 , 0.06, and micronutrients. Following transfer to a third solution, containing 5 mEq KNO_3 , 1 mEq $\text{Ca}(\text{NO}_3)_2$, 1 mEq MgSO_4 , 0.06 mEq KH_2PO_4 , and 0.5 mg B (as H_3BO_3) per liter of solution, uptake of ions during a 96 hour period was measured. Positive values indicated net absorption; negative values, loss from plant to the solution.

Nutrient		Rate of Nutrient Uptake at pH ¹						
		3 ²	4	5	6	7	8	9
		mEq per plant per 96-hour period						
Bermuda grass (<i>Cynodon dactylon</i>)								
1	K	3.38	4.61	4.53	4.53	4.33	5.17	4.53
2	Ca	0	0.35	0.90	0.90	0.90	1.25	1.25
3	Mg	0.82	1.07	1.07	1.15	1.15	1.48	1.23
4	NO ₃	10.69	10.14	10.45	10.08	10.14	10.08	10.45
5	H ₂ PO ₄	0.29	0.72	0.67	0.64	0.78	0.47	0.09
Lettuce (<i>Lactuca sativa</i>)								
6	K	-0.44	3.14	5.07	6.66	6.09	5.86	6.53
7	Ca	-0.30	0.45	0.65	0.90	0.90	0.90	1.55
8	Mg	-0.33	0.66	0.99	1.15	0.99	0.82	1.15
9	NO ₃	1.01	5.25	7.23	9.13	7.87	7.02	8.29
10	H ₂ PO ₄	-0.11	0.26	0.45	0.65	0.58	0.42	0.16
Tomato (<i>Lycopersicon esculentum</i>)								
11	K	-0.51	5.40	9.80	9.11	10.32	9.80	10.98
12	Ca	0	1.30	4.29	4.29	4.59	4.29	3.64
13	Mg	0	2.14	3.95	6.25	6.00	6.82	5.75
14	NO ₃	4.69	26.48	25.12	25.84	24.94	20.61	20.29
15	H ₂ PO ₄	0.03	1.51	1.85	1.89	2.86	1.52	0.14

/1/ pH adjusted by addition of either NaOH or H_2SO_4 . /2/ Roots were visibly injured and plants failed to grow.

202. EFFECT OF pH ON ZINC ABSORPTION: EXCISED ROOTS

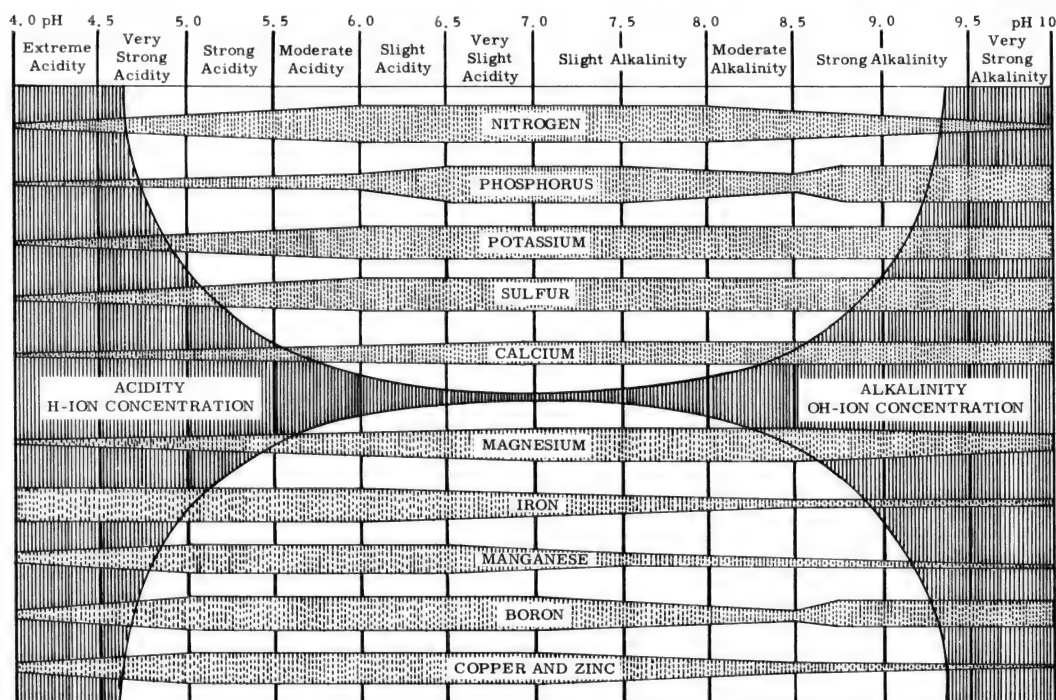
Data are applicable to excised, segmented roots of barley (*Hordeum vulgare* var. Sacramento), placed in solutions containing 0.0005 mEq zinc per liter. Values are mEq per 1000g roots, wet-weight, per 3 hr period.

Values are mEq per 1000g roots, wet weight, per 5 min period;							
Acid-Base ¹		Zn Uptake		Acid-Base ¹		Zn Uptake	
	pH	mEq/1000g roots			pH	mEq/1000g roots	
1	HCl-KOH	4.8	0.07	25	HCl-Ca(OH) ₂	4.5	0.02
2		5.3	0.18	26		5.0	0.04
3		6.4	0.33	27		6.1	0.12
4		7.0	0.32	28		7.0	0.15
5		8.0	0.30				
6		9.0	0.26	29		9.0	0.18
7	HNO ₃ -KOH	4.6	0.05	30	HNO ₃ -Ca(OH) ₂	4.6	0.02
8		5.2	0.09	31		4.8	0.03
9		6.4	0.25	32		6.1	0.08
10		7.0	0.29	33		7.0	0.12
11		8.0	0.31	34		8.0	0.14
12		9.0	0.24	35		9.0	0.19
13	H ₂ SO ₄ -KOH	4.4	0.04	36	H ₂ SO ₄ -Ca(OH) ₂	4.3	0.01
14		4.9	0.08	37		4.8	0.03
15		5.8	0.23	38		5.4	0.05
16		7.0	0.30	39		7.0	0.12
17		8.0	0.32	40		8.0	0.15
18		9.0	0.25	41		9.0	0.17
19	H ₃ PO ₄ -KOH	4.4	0.03	42	H ₃ PO ₄ -Ca(OH) ₂	4.0	0.01
20		5.2	0.10	43		4.3	0.01
21		6.6	0.27	44		6.2	0.11
22		7.0	0.31	45		7.0	0.16
23		8.0	0.31	46		8.0	0.17
24		9.0	0.14	47		9.0	0.14

/1/ Solutions made to pH 9 or above with base, then acidified with requisite amounts of acid. Initial concentration of KOH, 0.082 mEq per liter of H_2O ; that for $\text{Ca}(\text{OH})_2$, 0.090 mEq per liter.

203. EFFECT OF SOIL REACTION ON AVAILABILITY: CHEMICAL ELEMENTS

Diagram illustrates the general trend of relation of soil reaction (pH) and associated factors to the availability of plant nutrient elements. Each element is represented by a band as labeled. The width of the band at any particular pH value indicates the relative favorableness of this pH value and associated factors to the presence of the elements in question in readily available forms (the wider the band the more favorable the influence), but not to actual amount necessarily present. The latter is influenced by other factors, e.g., cropping and fertilization. The width of the heavily cross-hatched area between the curved lines at any pH is proportional to the hydrogen-ion concentration (intensity of acidity) to the left of pH 7, and to the OH-ion concentration (intensity of alkalinity) to the right of pH 7.



204. NUTRITIONAL CHARACTERISTICS OF VITAMINS: VERTEBRATES

Functions	Deficiency Signs	Excess Signs
<p>VITAMIN A (Anti-xerophthalmia factor, xerophthol)</p> <p>Required by all vertebrates studied (man, cattle, dog, guinea pig, hedgehog, horse, monkey, rabbit, rat, chicken, turkey). May be formed within the organism from one of the carotenoid provitamins, alpha-, beta-, gamma-carotene, or cryptoxanthin. Exists as vitamin A₁ in marine fishes and land vertebrates, as both A₁ and A₂ in amphibia and anadromous and catadromous fishes, and as A₂ (in place of or in addition to A₁) in fresh-water fishes.</p>		
Stimulates growth and development. Maintains epithelium. Vitamin A is a precursor for retinene which, with the visual proteins, forms the photosensitive visual pigments (rhodopsin, porphyropsin, iodopsin).	Retarded growth of young (man, rat, chick, turkey); inability to stand on hind legs (swine). Localized overgrowth of bone (cattle, rat). Night blindness; photophobia (man). Degenerative changes in epithelium of eye; xerophthalmia, keratomalacia in severe deficiency (man, rat). Skin (man, rat) and mucosae (man), metaplasia, hyperkeratinization, cornification, desquamation. Optic nerve degeneration, possible result of skull overgrowth and pressure (cattle, rat). Decreased egg production (chicken); irregular estrus -- sterility, male (rat). Odontoblast atrophy (man, rat). Deficiency accentuated by: factors impairing digestion or absorption of fat, excessive ingestion of mineral oil, hyperthyroidism (inhibits conversion of provitamins to vitamin A ₁).	Hypoprothrombinemia (rat); increased serum lipids, phosphatase; decreased serum proteins (man). Fragility, hyperostosis, cortical thickening of long bones, periosteal swellings, pain (man). Dry, exfoliated epithelium. Mouth desquamation, hyperemia of skin and mucosae (man). Liver enlargement (man). Telangiectasis.
<p>ASCORBIC ACID (Vitamin C; anti-scorbutic factor)</p> <p>Required by man, other primates; guinea pig.</p>		
Protects hydrogen carriers. Promotes oxidation of fatty acids, oxidation of aromatic amino acids, conversion of folic acid to folinic acid, formation of intercellular substances. Increases phagocytic activity. Prevents and cures scurvy. Alleviates some effects of vitamin A lack and moderate excess. Prevents development of deficiency signs of vitamin E deficient diets (chick, guinea pig). Treatment of shock, wounds, infections. Protects adrenal oxy-steroids from destruction by liver (rat).	Loss of appetite, decline in physical activity; defective wound healing. Follicular keratosis (man); loss of luster, roughening of hair. Disorientation of cells in growing region of bone and teeth; beading of ribs; failure of chondroblast and osteoblast and ameloblast differentiation and maturation. Loosening of teeth; swollen gums. Anemia with decreased red cells; increase in circulating leukocytes. Failure of differentiation and maturation of fibroblasts. Capillary hemorrhages, particularly in subcutaneous and intramuscular areas. Swelling, atrophy, soreness of muscles leading to "face ache posture." Increased cholesterol in adrenals in early deficiency, decrease in late deficiency. Reduction of cytoplasm and indistinctness of cell membrane, increased respiration rate early in deficiency, decrease in late stages; lowering of temperature in late stages.	Hypervitaminosis doubtful if calcium content of diet is sufficient. Massive doses by injection lead to sudden death.
<p>BIOTIN (Anti-egg-white factor; vitamin H)</p> <p>The need for the vitamin may be met under normal circumstances by intestinal bacterial synthesis in most animals. Need demonstrated for man, calf, dog, monkey, mouse, rabbit, rat, chicken, turkey.</p>		
Growth factor for all vertebrates studied. Believed to be required by all rapidly growing tissues. Involved in such metabolic processes, as: carboxylation and decarboxylation of Krebs Cycle acids; deamination of aspartic acid, serine, threonine; synthesis of citrulline, synthesis of unsaturated fatty acids. Prevention of "slipped tendon" (chick).	Seborrheic skin pathology. Scaly, greasy dermatitis (dog, monkey, rat, rabbit, chicken) followed by extreme hyperkeratosis after long deficiency. Scaly dermatitis in volunteers fed 200 grams of egg white daily (man). Spectacle alopecia (rodents); alopecia (monkey) may be extreme. Atrophy of lingual papillae (man). Spasticity (rat); paralysis of hindquarters (rat). Precordial distress; electrocardiographic changes (man). Anorexia, lassitude, sleeplessness, muscle pain (man); perosis (chick). Spontaneous deficiency rare, seen in chick. Feeding raw egg white (avidin) necessary to produce deficiency in most animals.	1 g/kg body weight not toxic to mice. Relatively non-toxic to all animals.
<p>CHOLINE (No single analogue can carry out all functions of the vitamin; several compounds can replace choline in one or more of its functions).</p> <p>Required by most or all vertebrates, especially the young, including dog, guinea pig, rat, chicken, turkey.</p>		
Source of transferable (labile) methyl (CH ₃) groups; is enzymatically transformed to betaine which transfers the methyl group. May be readily replaced as a methyl donor by betaine, dimethyl thetine, or methionine. Donor of methyl groups for synthesis of methionine (in presence of homocysteine), purines, etc. Synthesis of phospholipids, i.e., lecithin. Participates in creatine formation (rat). Precursor of acetylcholine. Essential for normal nutrition and egg production (chicken). Essential for lactation (hamster, rat). Necessary for normal liver function (dog, mouse, rat, chicken). A direct catalytic role of choline in intermediate metabolism has not been demonstrated. Therapeutic uses: cure of fatty liver and certain forms of liver cirrhosis (dog, rat); prevention of perosis ("slipped tendon" (chicken, turkey)).	Increased mortality (chicken, turkey). Liver: fatty degeneration and cirrhosis of liver (dog, rabbit, rat); prolonged prothrombin and bromsulphalein times, changes being marked in animals on high protein diets (rat); liver carcinoma from chronic deficiency (mouse, rat, chick). Increased serum phosphatase (rat). Kidney is enlarged, hemorrhagic congestion, necrosis of renal tubule, epithelium and glomeruli (rat); granular atrophy; hypertension in consequence of early kidney lesions, decrease in alkaline phosphatase activity and fat deposition (rat). Paralysis (young rat). Muscle weakness (guinea pig). Decreased egg production, ovarian abortion (chicken, turkey). Intracranial bleeding in young, born of choline deficient females (rat). Small subcutaneous and adrenal hemorrhages; marked anemia (guinea pig).	Inhibition of erythrocyte formation (dog). Diarrhea (man). Edema of legs (man).

204. NUTRITIONAL CHARACTERISTICS OF VITAMINS: VERTEBRATES (Continued)

Functions	Deficiency Signs	Excess Signs
<p>5</p> <p style="text-align: center;">COBALAMIN (Vitamin B₁₂; vitamin B_{12a}; vitamin B_{12b}; cyanocobalamin; hydroxycobalamin)</p> <p style="text-align: center;">Required by most or all vertebrates studied. Probably the anti-pernicious anemia principle of liver.</p>		
Growth factor (man, mouse, rat, swine, chicken, turkey). Utilization of oral cobalamin potentiated by gastric juice; in man, "intrinsic" factor necessary for the utilization of cobalamin, the "extrinsic" factor. In methylation reactions (rat, chick). Combined action with folic acid group. Therapeutic uses: pernicious anemia -- the vitamin is anti-anemic, relieves linqual manifestations and reverses degenerative changes in the spinal cord unless damage is irreversible (man); sprue (man).	Megaloblastic bone marrow (man). Macrocytic, hyperchromic anemia (man). Degenerative changes in the spinal cord. Glossitis (man).	Polycythemia of non-ruminant animals.
<p>6</p> <p style="text-align: center;">VITAMIN D (Anti-rachitic factor; calciferol; vitamin D₂; 7-dehydrocholesterol, vitamin D₃)</p> <p style="text-align: center;">Required by most vertebrates studied. Ultraviolet light converts the provitamins ergosterol and 7-dehydrocholesterol to D₂ and D₃ respectively.</p>		
Normal development of bone. Enhances absorption and retention of Ca and P; promotes P reabsorption by the renal tubules. Maintains alkaline phosphatase at the bone site.	Retardation of growth (man, others). Rickets. Skeletal abnormalities and deformities varying with degree and duration of deficiency (man, rat, others). Skeletal abnormalities are scars of functional and structural change and may persist long after the deficiency has been relieved. Degree of restoration may be extensive and continue over long periods. Rapidly growing regions of bones are most affected; persistent over-proliferation of cartilage; enlargement of ends of long bones; softness, weakness of bones, and deformation of stress and posture; osteomalacia; decalcification, fragility of non-growing bone. Faulty calcification of teeth, similar to deficiencies of vitamins A and C. Hypocalcemia, hypophosphatemia. Increase in plasma phosphatase. Myasthenia; atony, skeletal and gut muscle. Tetany, convulsions, spasmodic closure of glottis (man, rat). Deficiency accentuated by factors impairing digestion or absorption of fat, excessive ingestion of mineral oil; pregnancy; lactation. Degree of toxicity is an individual characteristic.	Early symptoms: anorexia, thirst, lassitude. Later symptoms: nausea, vomiting, diarrhea, abdominal discomfort, weight loss and debility. Hypercalcemia, hyperphosphatemia. Deposition of Ca salts in various organs. Dense calcification in long bone metaphyses at the expense of disphyseal calcification, in infants and growing young (man). Ca deposits, kidney damage and renal dysfunction; increased urinary excretion of Ca and P. Continued hypervitaminosis leads to death. Excessive doses may be cumulative. Hypercalcemia, high urinary Ca and renal damage have been noted eight months after treatment (125,000 - unit doses daily). The amount of dietary vitamin D which will produce signs of excess varies with individuals within the same species, and at different times within the same individual.
<p>7</p> <p style="text-align: center;">VITAMIN E (Alpha-, beta-, gamma-, delta-tocopherols; anti-sterility factor)</p> <p style="text-align: center;">Required by cattle, dog, guinea pig, hamster, mink, mouse, rabbit, rat, swine, chicken, duck, turkey. Significance, if any, in human nutrition, has not yet been established.</p>		
Biological anti-oxidant; protects unsaturated fatty acids, vitamin A against peroxidation. Participates in oxidation-reduction reactions. Therapeutic uses: treatment of skin collagenoses (man); protects against such toxic agents as carbon tetrachloride, chloroform, alloxan.	Irreparable degeneration of the testicular germinal epithelium (bull, mouse, rat, chicken); uterine necrosis, seminal vesicle necrosis (rat). Reproductive failure (swine, rat). Reduced egg hatchability, death of the embryo (chicken). Acute muscle degeneration (dog, guinea pig, hamster, rabbit, rat, chicken, duck, turkey). Acute encephalomalacia, degeneration of the cerebellum, nerve cell degeneration (chick). Ataxia, tremors, weakness, opisthotonos (chicken). Paralysis (suckling rat, born of vitamin E deficient mother). Creatinuria. Generalized exudative diathesis (chick). Liver necrosis, degeneration (mouse, rat, swine). Some causes of deficiency signs, other than dietary deficiency of the vitamin are: any factor impairing digestion or absorption of fat, as inflammation of intestinal mucosa, sprue, or chronic diarrhea; excessive ingestion of mineral oil; relatively greater requirement during pregnancy and lactation.	None listed.
<p>8</p> <p style="text-align: center;">FOLIC ACID GROUP (Folacin; pteroylglutamic acid (PGA); folinic acid; citrovorum factor; vitamin M; vitamin B₉; vitamin B₁₀; factor U; L. casei factor; Norite eluate factor)</p> <p style="text-align: center;">Required by most vertebrates studied, except ruminants and others whose need is satisfied by intestinal bacterial synthesis. Essential for man, dog, guinea pig, fox, mink, chicken, duck, goose, turkey, fish, sulfa-treated lamb and rat.</p>		
Growth and hematopoietic factor (monkey, fox, mink, chick, on purified rations). Production and utilization of formate. Methylation reactions. Introduction of the 2- and 8-carbon atoms into the purine ring and the amidine carbon into histidine. (Continued on next page)	Retardation of growth. Sprue (man, monkey), megaloblastic bone marrow (man, monkey, others), macrocytic, hyperchromic anemia (man, monkey); macrocytic anemia, with ultimate anisocytosis (chick, turkey); cytopenia (monkey). (Continued on next page)	Relatively non-toxic. Males more resistant than females (mouse). (Continued on next page)

204. NUTRITIONAL CHARACTERISTICS OF VITAMINS: VERTEBRATES (Continued)

	Functions	Deficiency Signs	Excess signs
8	FOLIC ACID GROUP (concluded)		
	Tyrosine oxidation. p-Aminobenzoic acid is a part of folic acid molecule. Vitamin-like action of PABA caused by above relations. Therapeutic uses: treatment of sprue (man); nutritional macrocytic anemia; certain megaloblastic, macrocytic anemias of infancy (man); macrocytic anemia of pregnancy (man); added to practical rations as a growth stimulant (mink).	chick); leukocyte abnormalities (monkey, rat, chick); infarction of the spleen (rat). Poor feather structure (chicken, turkey); abnormal feather pigmentation (chicken); graying of the pelage (rat). Perosis (chick, turkey). Impaired reproduction (rat, chicken); lowered hatchability of eggs (chicken). Impaired lactation (rat, mouse). Neck paralysis (goose, turkey). Diarrhea and the absorptive difficulties in sprue (disorders of calcium metabolism; impaired absorption of fat and of vitamins).	Death by obstruction of the renal tubules with precipitated folic acid follows intake of toxic amounts. Intravenous LD ₅₀ = 600 mg/kg body weight (mouse); 500 mg/kg (rat); 410 mg/kg (rabbit); 120 mg/kg guinea pig.
9	INOSITOL (Myo-) (Mouse anti-alopecia factor; Bios I) Required by mouse and possible cotton rat and hamster.		
	Has been reported to stimulate growth when added to rations deficient in thiamine (rat) and to rations containing sulfonamides (rat, swine). Lipotropic factor. Prevents encephalomalacia and exudative diathesis in vitamin E deficiency (chick). Suggested essential for reproduction (hamster). Of doubtful significance as a vitamin.	Characteristic alopecia (loss of hair) followed by severe dermatitis -- mouse (under certain dietary conditions).	Non-toxic, so far as known.
10	VITAMIN K (Anti-hemorrhagic factor; phyloquinone) Required by man, dog, mouse, rabbit, rat, canary, chicken, duck, goose, pigeon, turkey, and others. In mammals, bacterial synthesis may satisfy the need in whole or in part.		
	Essential for the production of prothrombin in liver. A number of synthetic products having a quinoid nucleus have vitamin K activity, e.g., menadione (2-methyl-1,4-naphthoquinone).	Decline or failure of prothrombin synthesis. Decrease in blood prothrombin content, resulting in increased bleeding tendency after even slight trauma, multiple hemorrhages throughout all tissues (man, chicken); increased clotting time (man, others).	Toxicity relatively low. Vomiting (man); vomiting after oral dose of 180 mg of menadione (synthetic vitamin) (dog). Porphyrinuria (man, dog), albuminuria (dog). Prolonged clotting time (rabbit); cytopenia, hemoglobinemia (mouse). Lethal dose is 350 to 500 mg/kg body weight (rats).
11	NIACIN (-AMIDE) (Nicotinic acid (-amide); pellagra preventive (P.P.) factor; anti-blacktongue factor). Required by all vertebrates studied except calf, horse, sheep, whose need is supplied by intestinal flora. Most animals synthesize niacin from tryptophan. Animal tissues contain niacinamide; plant tissues contain mainly niacin.		
	A component of di- and triphosphopyridine nucleotides (DPN, Coenzyme I; TPN, Coenzyme II) which function as hydrogen acceptors in more than 50 metabolic reactions. Stimulates gastric secretion.	Delayed growth and development of young; diarrhea, dermatitis, and dementia, the "triad" of pellagra. Bilateral, symmetrical dermatitis, aggravated by sunlight, heat, inflammation (man, only); rarefaction of corium, keratinization, atrophy of sebaceous glands, desquamation. Swollen gills (trout). Poor feathering (chick). Stomatitis (man, dog, fox, swine, chicken, turkey); smooth glossitis (man); black-tongue (dog, cat, chick); large intestine -- atrophy, ulceration, cyst formation (man, dog, swine), diarrhea (man, dog, calf, rabbit, chick, duck, turkey); achlorhydria (man, swine); salivary drooling (dog). Macrocytic anemia (man, dog, rabbit, swine); leukopenia (dog, rabbit). Retrobulbar neuritis (man); encephalopathy, headache, dizziness, depression, delusions, dementia; locomotor difficulties, tremors, jerky movements, rigidity; altered tendon reflexes, numbness, paralysis (man). Perosis ("slipped tendon" -- chick, turkey poult). The syndrome of deficiency symptoms is referred to as "pellagra" in man and "blacktongue" in dogs, cats, and other animals.	Death follows very large doses; dogs on 2 grams/day die within 20 days; 2% niacinamide in diet inhibits growth (chick); 1% causes fatty livers; large doses of niacin cause ketosis (rat). Burning and itching of skin; elevation of skin temperature (man). Peripheral vasodilation (man). Paralysis of the respiratory center (rat). Ratio therapeutic dose: toxic dose = 1:1000.
12	PANTOTHENIC ACID Required by most or all vertebrates studied, including calf, dog, fox, guinea pig, hamster, monkey, mouse, swine, rat, chicken, duck, pigeon, turkey, and possibly man.		
	Growth factor for the animals mentioned above. As a component of Coenzyme A, functions in: enzymatic acetylation; fat, protein and carbohydrate metabolism; fat, phospholipid, and steroid synthesis.	Retarded growth in all animals. Specific dermatitis of mouth and feet (chicken); eczematous dermatitis (rat). Achro-motrichia (monkey, dog, fox, rat, mouse), spectacle alopecia (rat). Myelin degeneration of peripheral nerves (chick); chromatolysis of dorsal root ganglion cells (chick, swine). Spastic abnormalities of hindquarters, abnormal gait, ataxia (dog, mouse, swine); convulsions (dog). Hemorrhagic necrosis of adrenals. Secretion of red pigment by the Harderian gland ("bloody pigment" -- rat). Diarrhea with bloody stools (dog); anorexia, diarrhea, colitis (monkey, swine); necrosis of intestinal epithelium, abscesses followed by ulceration (rat). Anemia (dog, rat, monkey, swine). Necrosis of kidney (rat). Increased deposition of liver fat (dog, chick). Failure and abnormalities in reproduction; ocular changes. Burning sensations of hands, feet (man); increased non-protein nitrogen in severe deficiency (dog); death in severe deficiency.	100 grams have been given to man without ill effects. LD ₅₀ mouse: orally, 10 g; subcutaneously, 2.7 g; intraperitoneally, 0.9 g. LD ₅₀ rat: subcutaneously, 3.4 g/kg body weight.

204. NUTRITIONAL CHARACTERISTICS OF VITAMINS: VERTEBRATES (Concluded)

	Functions	Deficiency Signs	Excess Signs
13	<p align="center">PYRIDOXINE (VITAMIN B₆) GROUP (Pyridoxal, pyridoxamine, anti-acrodynia factor; factor Y)</p> <p>Required by most or all vertebrates studied, including man, synthesized by intestinal organisms in rat. Requirement by animals is increased with increased dietary protein, linseed oil meal, sucrose, and apparently decreased with increased dietary essential fatty acids, aureomycin. Occurs largely as pyridoxal in animal products and as pyridoxamine in plant products. In animals the three forms (pyridoxine, -al, -amine) are equally active when given by injection, but pyridoxine is the most active when administered orally.</p>		
	<p>As coenzyme (pyridoxal phosphate) for transaminase and codecarboxylase systems, kynurinate, cystathionase, serine and threonine dehydrase, cysteine desulfhydrase, and racemizing enzymes; in deamination of amino acids and the formation of urea nitrogen; in conversion of tryptophan to niacin; in metabolism of fatty acids. Necessary for normal adrenal-cortical function. Therapeutic uses: treatment of muscular dystrophies associated with pellagra (man); hyperemesis gravidarum (nausea of pregnancy); seborrheic dermatitis sicca (man).</p>	<p>Retarded growth (man; infant; guinea pig, rabbit, monkey, rat, chick); appetite and weight loss, reduced egg production, death (chick). Hypochromic anemia (man; infant); polymorphonuclear leukocytosis, lymphopenia (man); hypochromic, microcytic anemia with anisocytosis and irregular reticulocytosis (dog, swine, monkey, duck, chick); poikilocytosis (cattle), dilation, hypertrophy of right auricle and ventricle; increased plasma urea and NPN tachycardia and cardiac embarrassment (rat); mucus accumulation in thorax (dog); impaired antibody production (rat); degeneration in myelin sheaths of peripheral nerves and spinal cord (dog, swine); convulsions, epileptiform fits (rat, swine, chicken); ataxia (swine); convulsions (man; infant); weakness, nervousness, irritability, insomnia (man); deficiency signs produced by ingestion of desoxyypyridoxine; seborrhea-like lesions about eyes, nose, mouth; cheilosis, glossitis, stomatitis (man); denudation of hair from paws, snout, ear tips, thickening of ears (rat); dermatitis, bald patches (monkey). Increased urea, ammonia, uric acid, creatinine (dog); tryptophan metabolites in urine (dog, hamster, mouse, rat); large amounts of xanthurenic acid (man). Anorexia, unthriftiness (cattle).</p>	<p>Convulsions 24 hr after LD₅₀ dose (rat). Daily feeding of 10 mg/kg body weight for 3 months had no effect (monkey, dog, rat). LD₅₀ rat: subcutaneously, 3 g/kg body weight; orally, 4 g/kg.</p>
14	<p align="center">RIBOFLAVIN (Vitamin B₂, or G; lactoflavin, ovoflavin, hepatoflavin)</p> <p>Required by most or all vertebrates studied.</p>		
	<p>As riboflavin-5-phosphate in flavo-protein enzymes, e.g., "Warburg's yellow enzyme," cytochrome-c-reductase, riboflavin-adenine-nucleotide. As prosthetic group in enzymic hydrogen carriers, e.g., D-amino acid oxidase, xanthine oxidase, succinic dehydrogenase. Role in the visual mechanism of the retina.</p>	<p>Cessation or retardation of growth (rat, others). Epidermal atrophy, dermatitis, greasy scaling especially of nasolabial folds, cheeks, chin (man); cheilosis, angular stomatitis, lesions of lip and mouth corners (man). Myelin degeneration of nerves (dog, mouse, rat, swine, chicken); central neuritis (man); lack of coordination, faulty grasp reflex (monkey); curled toe paralysis (chicken); partial paralysis of legs (rat). Muscle weakness (dog, monkey). Mild photophobia, dimness of vision and decline of visual acuity; soreness of eyes and lids (man); cornea -- cloudiness, vascularization, cataract, opacity, ulceration (man, dog, rat). Congenital skeletal malformations in offspring of riboflavin-deficient females (rat). Requirement increased in pregnancy and lactation.</p>	<p>5,000 times the therapeutic dose is tolerated (rat, mouse). Toxic amounts intraperitoneally cause anuria, renal concretions (rat). Paresthesia, itching (man).</p>
15	<p align="center">THIAMINE (Vitamin B₁; aneurin)</p> <p>Required by most or all vertebrates studied, except ruminants whose need is satisfied by intestinal synthesis.</p>		
	<p>Essential for normal growth, appetite, digestion, gastrointestinal tonus, nerve activity, carbohydrate metabolism (as cocarboxylase participates in decarboxylations, oxidations, dismutations, and condensations leading to CO₂ formation).</p>	<p>Retardation of growth; anorexia (man, others). No peripheral nerve degeneration (mammals). Convulsions, hyperesthesia, anesthesia, opisthotonos (pigeon, chicken, turkey). Dilation of the heart, myocardial lesions (dog, fox, rat, swine); bradycardia (monkey, cat, dog, rat, swine). Edema (dog, fox, rat, swine). Gastrointestinal disturbances (man). Accumulation of pyruvic acid in blood and tissues. Decrease in urinary citric acid (rat). Deficiency disease in man: beriberi (sometimes subdivided into cardiac, wet, and dry [neuritic, paraplegic] beriberi).</p>	<p>Vascular: hypotension (man, dog, rabbit).</p>
16	<p align="center">ESSENTIAL UNSATURATED FATTY ACIDS (Arachidonic acid, linoleic acid, linolenic acid)</p> <p>Required by rat, mouse, guinea pig, swine, others. Ordinarily not regarded as a vitamin.</p>		
	<p>Essential to growth and reproduction (rat). Serve as building units of the phospholipids. Catalyze the oxidation of saturated fatty acids in vitro. Exercise a protective action in pyridoxine deficiency (rat).</p>	<p>Eczema (man). Retardation or cessation of growth; metabolic rate; scaliness on feet and tail; alopecia; disturbances in reproduction; kidney and urinary tract lesions; increased water intake (rat).</p>	<p>Changes from normal in composition of stored fat.</p>

205. NUTRIENTS: CALORIE VALUE

Values are Calories per gram of ingested nutrient.

P = plant; A = animal; F = fiber; M = mixed; NFE = nitrogen-free extract.

Nutrients for:		Total	Lost, Ru- men Gas ²	Lost, Feces ²	Virtually Absorbed ³	Lost Urine ³	Metabolized Net ⁴	Av. ⁵
1	Man							
2	Protein	P 5.65		0.85	4.80	1.06	3.74	4.0
3	Carbohydrate	A 5.65		0.15	5.50	1.21	4.29	
4	Fat	P 4.15		0.15	4.00	0	4.00	4.0
5		A 3.90		0.10	3.80	0	3.80	
6		P 9.30		0.95	8.35	0	8.35	9.0
7		A 9.40		0.45	8.95	0	8.95	
8	Monkey							
9	Protein	P 5.65		0.56	5.09	1.68	3.41	3.0
10	Carbohydrate	A 5.65		0.56	5.09	2.04	3.05	
11	Fat	P 4.1		0	?	0	?	
12		A 9.3		0	?	0	?	
13	Cattle							
14	Protein	P 5.65		1.64	4.01	1.30	2.71	2.7
15	Carbohydrate	F 4.25	0.33	1.89	2.03	0	2.03	2.6
16	Fat	NFE 4.23	0.47	0.95	2.81	0	2.81	5.8
17		P 8.72 ⁶		2.90	5.82	0	5.82	
18	Chicken							
19	Protein	M 5.70		1.37	4.33	0.87	3.46	3.5
20	Carbohydrate	M 4.20		0.84	3.36	0	3.36	3.4
21	Fat	M 9.47 ⁷		1.89	7.58	0	7.58	7.6

/1/ By bomb calorimeter. /2/ From fermentation of fiber and NFE. A 550 kg cow may lose 4000 Calories/da (400 liters methane). /3/ Total calorie value minus that lost in feces (in rumen gas and feces for ruminants). /4/ Net physiological energy available for heat, activity, growth. /5/ Average values rounded off. /6/ Mean of 7.96 for fat from roughage and 9.47 for fat from grain. /7/ From grain.

206. FEED UTILIZATION, ACCUMULATIVE EFFICIENCY FOR GROWTH: VERTEBRATES

Unless otherwise indicated, values are grams gain in body weight per gram of feed¹ consumed (or pounds gain per pound of feed consumed). Values are calculated by dividing gain in weight from birth to per cent of mature weight by total weight of feed consumed since birth.

		MW = mature weight			
		10% MW	25% MW	50% MW	90% MW
1	Cattle, dairy, large	♂ 0.45	0.26	0.17	
2		♀ 0.54	0.31	0.16	0.05
3	Cattle, dairy, small	♂ 0.39	0.33	0.16	
4		♀ 0.44	0.27	0.20	0.07
5	Cattle, beef	♂ 0.62	0.30	0.15	
6		♀ 0.61	0.25	0.14	
7	Rat, Sprague-Dawley	♂ 0.41	0.31	0.15	
8		♀ 0.44	0.34	0.14	
9	Rat, Wistar	♂ 0.37 ³	0.27 ³	0.20 ³	
10	Swine ²	♂ 0.45	0.41	0.33	
11		♀ 0.45	0.4	0.3	0.14
12	Chicken, white leghorn	♂ 0.53	0.45	0.35	
13		♀ 0.54	0.43	0.33	
14	Chicken, heavy breeds	♂ 0.55	0.42	0.34	0.19
15	Turkey, Beltsville small ⁴	♂ 0.50	0.37	0.31	

/1/ On a dry weight basis. /2/ Based on 56-day weaning weight, and feed consumption figures calculated for periods: 56-98 days, 98-140 days, and 140-180 days. /3/ Extrapolated. Calculated on basis of mature weight of 600 pounds. /4/ Values for broad-breasted bronze turkeys are the same, but a value of 0.23 is given at 90% mature weight.

207. NUTRIENTS, APPARENT DIGESTIBILITY AND ABSORBABILITY: VERTEBRATES

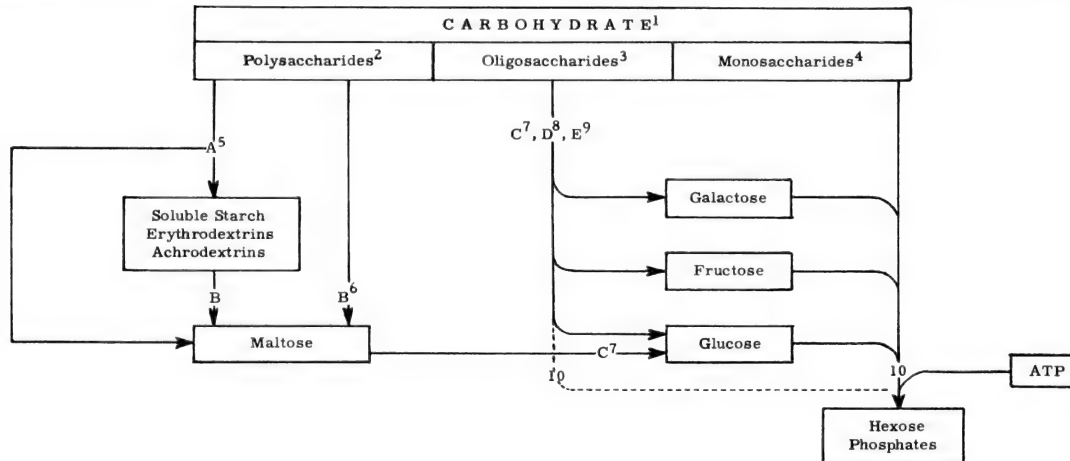
Values are grams of protein, fat or carbohydrate digested and virtually absorbed per 100 grams of the nutrient ingested as a component of the food or feed listed. The quantity digested and absorbed is taken as the quantity of the nutrient ingested minus the quantity subsequently found in the feces. Values for man are for food as commonly prepared for ingestion.

Food- or Feedstuff	Man			Cattle ¹			Horse ¹			Chicken		
	Protein	Carbo- hydrate	Fat	Protein	Carbohydrate		Protein	Carbohydrate		Protein	Carbo- hydrate	Fat
					Fiber	NFE ²		Fiber	NFE ²			
1	Animal products ³	97	98	95								
2	Bone meal			69						87	34	93
3	Buttermilk, dried			90		94				69	71	95
4	Eggs	97	98	95								
5	Fats			95								
6	Fish meal			88						75	35	83
7	Meat and fish	97		95								
8	Meat scrap			82						61	60	90
9	Milk, milk products	97	98	95		98						
10	Milk, skim, dried			90		93				75	66	57
11	Plant products ³	85	97	90	70?	40?	76?	77?		76?	69?	80?
12	Barley			70		88		88	39	73	80	75
13	Corn, whole ground	60	96	90	63		88	83	69	89	59	86
14	Cottonseed meal			81	57	80		92	85	29	49	90
15	Macaroni, spaghetti	86	98	90								
16	Oatmeal, rolled oats	76	98	90	90	80		98	96			
17	Oats, whole grain			74		76		84	79	44	79	80
18	Rice, white	84	99	90								
19	Soybean oil meal ⁴			90	57	91		38				
20	Wheat, 85-93% extraction	83	94	90								
21	Wheat bran			76	30	76		74	73	22	53	27
22	Fruit	85	90	90								
23	Potatoes	74	96	90	55		91	1	63	75	101	42
24	Sugar		98				97		70	32	83	50
25	Green roughages											
26	Kentucky bluegrass			71	70	64		51				
27	Pasture grass, mixed			75	74	77		42	66	33	62	
28	Silage, corn			53	66	69		74				
29	Timothy			59	68	72		57				
30	Dried roughages											
31	Alfalfa hay			71	44	70		34	74	39	68	
32	Alfalfa meal			73	45	67		21				
33	Clover hay			63	56	69		58	56	38	64	29
34	Timothy hay			46	58	57		46	43	43	53	13

/1/ Digestibility of roughages is determined by feeding one roughage alone, while that of concentrates and grains is determined by difference, e. g., feeding the material in conjunction with a roughage the digestibility of which has been determined. /2/ Nitrogen-free extract. /3/ Variety not specified. /4/ Solvent extracted.

208. PATHWAYS OF CARBOHYDRATE DIGESTION AND ABSORPTION: MAN, LABORATORY MAMMALS

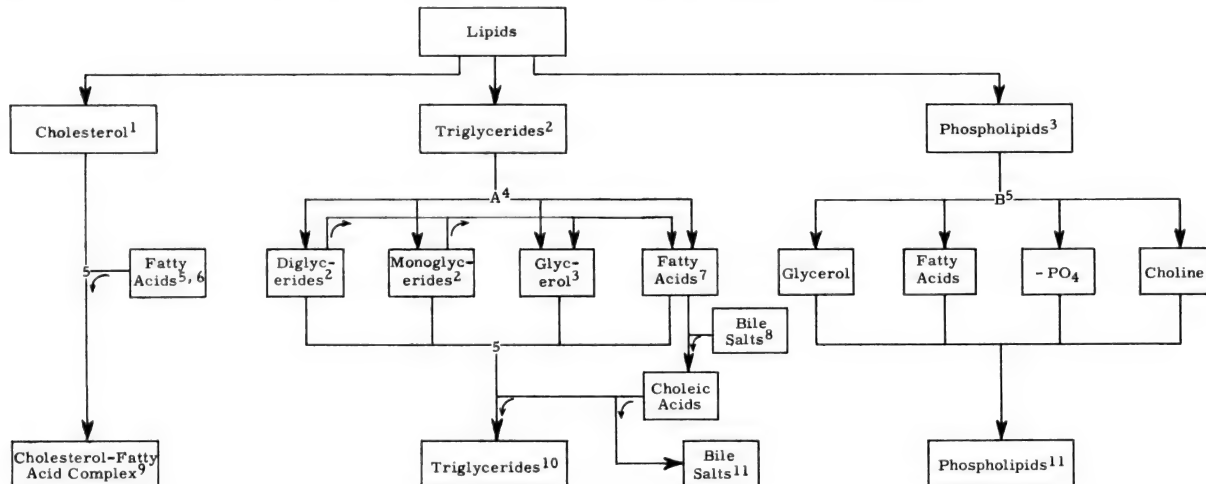
Carbohydrate digestion is the enzymatic hydrolysis of poly- and oligosaccharides into their monosaccharide components which are then absorbed into the blood stream. Monosaccharides are phosphorylated to hexose-6-PO₄(?) as they enter the intestinal mucosa and then dephosphorylated before they enter the blood stream. A = salivary amylase (ptyalin); B = pancreatic amylase (amylpsin); C = maltase; D = sucrase (invertase); E = lactase.



/1/ Ingested. /2/ Polysaccharides including glycogen, starch dextrins and cellulose are made up of many monosaccharide (simple sugar) molecules. Cellulose, although made up of glucose molecules is not digestible by mammals. /3/ Oligosaccharides are carbohydrates composed of only a few (down to two in the case of disaccharides) molecules of monosaccharide. Sucrose contains glucose and fructose; maltose is composed of two molecules of glucose; and lactose contains glucose and galactose as constituents. /4/ Ingested monosaccharides are absorbed into the blood stream without breakdown. /5/ Salivary amylase not only converts polysaccharides to soluble starch, etc., but also breaks off some maltose. /6/ Pancreatic amylase hydrolyzes starches, dextrins and glycogen to maltose; uncooked starch is hydrolyzed to some degree by pancreatic but not by salivary amylase. The concentration of pancreatic amylase is increased by high carbohydrate intake. /7/ Maltase, in intestinal secretion, hydrolyzes each molecule of maltose to two molecules of glucose. /8/ Sucrase, in intestinal secretion, hydrolyzes sucrose to glucose and fructose. /9/ Lactase, in intestinal secretion, hydrolyzes sucrose to glucose and fructose. /10/ Possibly other hexoses.

209. PATHWAYS OF LIPID DIGESTION AND ABSORPTION: MAN, LABORATORY MAMMALS

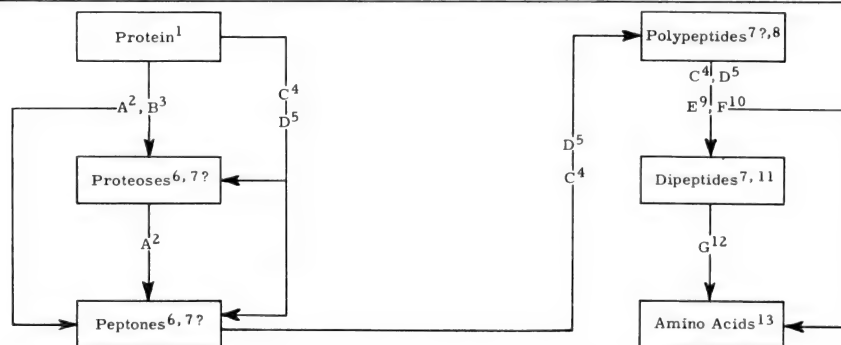
Details of digestion and absorption of lipids are not as well established as those for protein and carbohydrate. The pathways as presented may be expected to undergo modification with further research in the field. A = pancreatic lipase (steapsin); B = lecithinase.



/1/ Absorbed in the presence of fat (except in rabbits); excess cholesterol may hinder fat absorption. Some conversion to coprosterol by intestinal bacteria and excreted as such. Plant sterols are not absorbed(?). /2/ Tri-, di-, and monoglycerides = compounds of glycerol and 3 or 2 or 1 molecule fatty acid. Some absorption(?). /3/ Absorbed. Include (a) lecithins (= glycerol + fatty acids + phosphoric acid + choline) although there is some question whether unchanged lecithin can be absorbed; (b) cephalin (= glycerol + fatty acids + phosphoric acid + choline or serine, or inositol); (c) sphingomyelins (= fatty acid + phosphoric acid + choline + sphingosine). /4/ Lipolytic enzyme activated in intestinal lumen by bile salts, soaps, and certain proteins and amino acids. /5/ In succus entericus from intestinal mucosa. /6/ From hydrolysis of glycerides or phospholipids. /7/ Short-chain (i.e., 10 carbon or less) fatty acids, being water soluble, are readily absorbed into the intestinal mucosa; long chain fatty acids absorbed with the aid of bile salts (q.v.). /8/ In addition to forming choleic acid complexes with fatty acids, bile salts serve as emulsifying agent to hasten absorption of lipid digestion end products. /9/ Absorbed into lymphatic system. /10/ Mono- and diglycerides and fatty acids (from triglyceride or phospholipid hydrolysis) combine in the intestinal mucosa with endogenous glycerol (from dihydroxyacetone) to form triglycerides of different composition from those ingested. Those containing short-chain fatty acids are absorbed chiefly into the portal blood stream; the more insoluble fats containing long-chain fatty acids are absorbed through the lacteals into the lymphatic system. /11/ Formed in intestinal mucosa and absorbed into lymph and portal blood.

210. PATHWAYS OF PROTEIN DIGESTION AND ABSORPTION: MAMMALS

Protein digestion, in the alimentary canal, comprises the enzymatic cleavage of the protein molecule into its component amino acids which are absorbed into the blood stream. Although the diagram is a summary of present knowledge of the field, controversy still exists with regard to some of the details. A = pepsin; B = rennin; C = trypsin; D = chymotrypsin; E = carboxypolypeptidase; F = aminopolypeptidase; G = dipeptidase.



/1/ Native, denatured, or coagulated; some native protein may be absorbed. /2/ Secreted by the gastric mucosa as pepsinogen; activated by HCl. Pepsin is an autocatalytic endopeptidase, hydrolyzing peptide bonds in the interior of the protein molecule. /3/ In gastric juice of the young of some mammals, but probably not the adults; converts soluble calcium caseinate to insoluble calcium paracaseinate (clot). /4/ Secreted in pancreatic juice as trypsinogen in response to secretin from the small intestine; activated by enterokinase. Trypsin is an autocatalytic endopeptidase, hydrolyzing native proteins to proteoses, peptones, and polypeptides by splitting peptide bonds involving a basic nitrogen (as in lysine, arginine). /5/ Secreted in pancreatic juice as chymotrypsinogen in response to secretin; activated by trypsin. Chymotrypsin is an endopeptidase, hydrolyzing native proteins to proteoses, peptones, and polypeptides by splitting peptide bonds involving an aromatic group (as in tyrosine, phenylalanine). /6/ Secondary protein derivatives of molecular weight less than 1000, exclusive of polypeptides and simpler degradation products. /7/ Some absorption. /8/ A compound containing more than two amino acids joined by peptide linkages. /9/ An exopeptidase in pancreatic juice removing successively amino acids with free carboxyl groups from the end of the peptide chain, thus hydrolyzing polypeptides to simpler peptides and amino acids. /10/ Secreted by intestinal mucosa in succus entericus in response to enterocrinin, secretin, and presence of food; an exopeptidase, removing amino acids with free amino groups from the end of the peptide chain, thus hydrolyzing polypeptides to simpler peptides and amino acids. /11/ Dipeptides contain two amino acids. /12/ Secreted by intestinal mucosa in succus entericus; hydrolyzes dipeptides to amino acids by breaking the peptide linkage. /13/ Absorbed by intestinal mucosa; probably a stereochemical mechanism favoring absorption of L-amino acids.

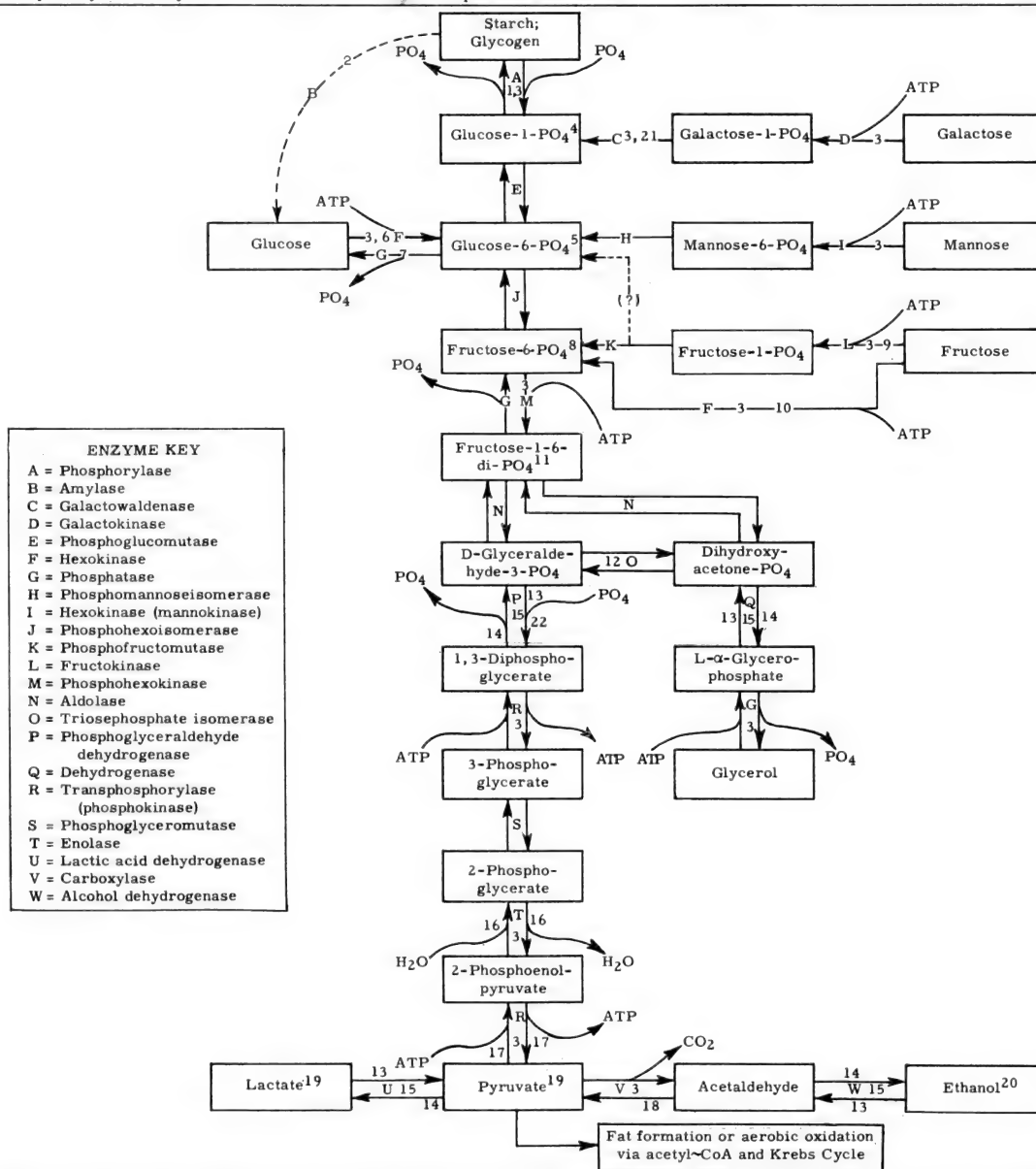
211. PATHWAYS OF AMINO ACID METABOLISM

Amino Acid	Product of Oxidative Deamination or Transamination	Product of Decarboxylation	Pathways and Products of Metabolism ¹
1 L-Alanine	Pyruvic acid		
2 L-Arginine	α -Keto- δ -guanidovaleric acid	Agmatine	Arginine \rightarrow ornithine + urea; arginine \rightarrow citrulline + NH_3 .
3 L-Asparagine	α -Ketosuccinamic acid		Asparagine \rightleftharpoons aspartic acid + NH_3 ; α -ketosuccinamic acid \rightarrow NH_3 + oxalacetic acid.
4 L-Aspartic acid	Oxalacetic acid	α -Alanine, β -alanine	Aspartic acid + carbamyl phosphate \rightarrow PO_4^{\equiv} + carbamyl aspartic \rightarrow pyrimidines; aspartic acid \rightleftharpoons (a) fumaric acid + NH_3 , (b) homoserine \rightleftharpoons threonine.
5 L-Citrulline	α -Keto- δ -carbamidovaleric acid		Citrulline + aspartic acid + ATP \rightarrow ADP + PO_4^{\equiv} + argininosuccinic acid \rightleftharpoons arginine + fumaric acid; citrulline + PO_4^{\equiv} \rightleftharpoons ornithine + carbamyl phosphate; carbamyl phosphate + ADP \rightleftharpoons CO_2 + NH_3 + ATP.
6 L-Cysteine & L-cystine	β -Mercaptopyruvic acid		β -Mercaptopyruvic acid \rightarrow pyruvic acid + S ; cysteine \rightarrow H_2S + NH_3 + pyruvic acid; cysteine \rightarrow cysteine sulfenic acid \rightarrow cysteine sulfinic acid \rightarrow (a) cysteic acid \rightarrow taurine, (b) hypotaurine, (c) via transamination \rightarrow β -sulfinylpyruvate \rightarrow pyruvate + SO_3^{\equiv} ; 2 cysteine \rightleftharpoons cystine.
7 L-Glutamic acid	α -Ketoglutaric acid	γ -Aminobutyric acid	See ornithine, proline, histidine, glutamine.
8 L-Glutamine	α -Ketoglutaric acid		Glutamine \rightleftharpoons glutamic acid + NH_3 ; α -ketoglutaric acid \rightarrow NH_3 + α -ketoglutaric acid.
9 Glycine	Glyoxylic acid		Glycine + 1 carbon fragment (CH_2O or HCOOH) \rightleftharpoons serine; glyoxylic acid \rightarrow formate + CO_2 .
10 L-Histidine	β -Imidazolepyruvic acid	Histamine	Histidine \rightarrow (a) urocanic acid \rightarrow glutamic acid + NH_3 + formate, (b) carnosine, (c) anserine; histamine \rightarrow imidazole acetic acid \rightarrow NH_3 + formyl aspartic acid.
11 L-Hydroxyproline	α -Keto- γ -hydroxy- δ -aminovaleric acid		See proline.
12 L-Isoleucine	α -Keto- β -methylvaleric acid		α -Keto- β -methylvaleric acid \rightarrow CO_2 + α -methylbutyryl CoA \rightleftharpoons tiglyl CoA \rightleftharpoons α -methyl- β -hydroxybutyryl CoA \rightleftharpoons α -methyl acetoacetyl CoA \rightleftharpoons acetyl CoA + propionyl CoA.
13 L-Leucine	α -Ketoisocaproic acid		α -Ketoisocaproic acid \rightarrow CO_2 + isovaleryl CoA \rightleftharpoons seneciyl CoA \rightleftharpoons β -hydroxyisovaleryl CoA \rightleftharpoons CO_2 + β -hydroxy, β -methyl glutaryl CoA \rightleftharpoons acetoacetic acid + acetyl CoA.
14 L-Lysine	α -Keto- ϵ -aminocaproic acid	Cadaverine	Lysine \rightarrow α -aminoadipic acid \rightarrow α -ketoadipic acid \rightarrow glutaric acid; α -keto- ϵ -aminocaproic acid \rightarrow dihydronicotinic acid \rightarrow pipercolic acid.
15 L-Methionine	α -Keto- γ -methiolbutyric acid		Methionine \rightarrow labile CH_3 + homocysteine \rightarrow (a) homocysteic acid, (b) H_2S + NH_3 + α -ketobutyric acid, (c) + serine \rightarrow cystathionine \rightarrow cysteine + homoserine \rightarrow α -ketobutyric acid.
16 L-Ornithine	Glutamic- γ -semialdehyde or α -keto- δ -aminovaleric acid	Putrescine	Ornithine \rightleftharpoons (a) proline, (b) glutamic acid; see citrulline.
17 L-Phenylalanine	Phenylpyruvic acid	Phenylethylamine	Phenylalanine \rightarrow (a) tyrosine, (b) phenylpyruvic acid \rightarrow phenylacetic and phenyllactic acids.
18 L-Proline	Glutamic- γ -semialdehyde or α -keto- δ -aminovaleric acid		Proline \rightleftharpoons (a) ornithine, (b) glutamic acid, (c) \rightarrow hydroxyproline.
19 L-Serine	β -Hydroxybutyric acid	Ethanolamine	Serine \rightarrow NH_3 + H_2O + pyruvic acid; serine + indole \rightleftharpoons tryptophan; see glycine.
20 L-Threonine	α -Keto- β -hydroxybutyric acid		Threonine \rightarrow (a) NH_3 + H_2O + α -ketobutyric acid, (b) glycine + acetaldehyde; see aspartic acid.
21 L-Tryptophan	β -Indolepyruvic acid	Tryptamine	Tryptophan \rightarrow formylkynurenine \rightarrow formate + kynurenine \rightarrow (a) kynurenic acid, (b) anthranilic acid + alanine, (c) 3-hydroxykynurenine \rightarrow 3-hydroxyanthranilic acid \rightarrow nicotinic acid.
22 L-Tyrosine	p-Hydroxyphenylpyruvic acid	Tryptamine	p-Hydroxyphenylpyruvic acid \rightarrow 2,5-dihydroxyphenylpyruvic acid \rightarrow CO_2 + homogentetic acid \rightarrow fumarylacetoacetic acid \rightarrow fumaric acid + acetoacetic acid.
23 L-Valine	α -Ketoisovaleric acid		α -Ketoisovaleric acid \rightarrow CO_2 + isobutyryl CoA \rightleftharpoons methacrylyl CoA \rightleftharpoons β -hydroxybutyryl CoA \rightarrow CO_2 + propionyl CoA.

/1/ ADP = adenosine diphosphate; ATP = adenosine triphosphate; CoA = coenzyme A.

212. PATHWAYS OF CARBOHYDRATE METABOLISM (GLYCOLYSIS)

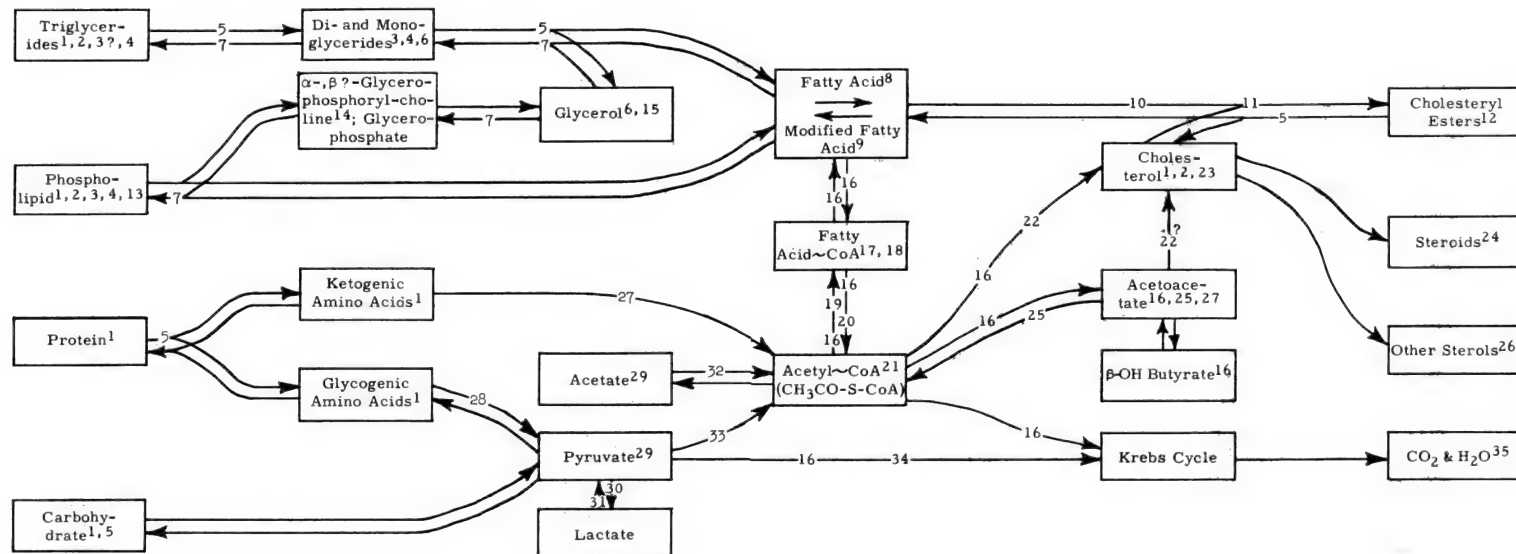
The pathway from stored or ingested carbohydrate to pyruvate is one of release of stored energy by anaerobic oxidation (glycolysis). Released energy is partly dissipated as heat and partly stored (temporarily) in the labile energy pool as "high energy phosphate" ($\sim\text{PO}_4$) by combination of $\sim\text{PO}_4$ with continuously available ADP (adenosine diphosphate) to form ATP (adenosine triphosphate). In the conversion of 1 mole of glucose (180 g), or of other monosaccharide to 2 moles of pyruvate (174 g), 2 moles of ATP are converted to ADP and 4 moles are formed from ADP, making a net gain of 2 moles of ATP, or approximately 20 kilocalories of readily available energy. If glucose-6- PO_4 has come from metabolic breakdown of glycogen, the cost is only 1 mole of ATP, making a net gain of 3 moles of ATP (approximately 30 kilocalories). The ATP is an immediate source of energy whose utilization (e.g., for muscular activity) is independent of oxygen supply. Aerobic oxidation (to carbon dioxide and water) begins where the present pathway ends and yields an additional 650 kilocalories per mole of hexose.



/1/ Adenylic acid and PO_4 required for activity in either direction. /2/ Digestion; glycogen and/or starch hydrolyzed to glucose in intestinal lumen. /3/ Mg^{++} required for this reaction. /4/ "Cori Ester." /5/ "Robison Ester." /6/ "Hexokinase reaction," assumed to be inhibited by growth hormone plus adrenal cortex hormone; and inhibition by these substances blocked by insulin, which thus favors conversion of glucose to glucose-6-phosphate. /7/ The reaction, glycogen to glucose-6- PO_4 to blood glucose, takes place in liver only; conversion of glucose to glucose-6- PO_4 to glycogen takes place in liver, muscle, and other tissues. /8/ "Neuberg Ester." /9/ In liver and muscle. /10/ In all tissue. /11/ "Harden-Young Ester." /12/ This reaction (to left) causes each step in the conversion to pyruvate to be doubled quantitatively; thus 1 mole of glucose gives rise to 2 moles of pyruvate. /13/ Hydrogen ions released. /14/ Hydrogen enters into the reaction. /15/ DPN acts as acceptor of released hydrogen ions, becoming DPNH in oxidative direction of the reaction; DPNH gives up hydrogen ions, becomes DPN, in reverse direction. Hydrogen ions accepted by DPN passed on in turn, to flavoprotein, cytochrome-c, cytochrome oxidase, molecular O_2 . If molecular O_2 not sufficiently available, hydrogen ions may be passed from DPNH to pyruvate forming lactate. /16/ Inhibited by fluoride. /17/ K^+ also required. /18/ Thiamine pyrophosphate is required as coenzyme. /19/ Pyruvate, followed by conversion to lactate when oxygen supply is deficient (cf Fn 15), ends glycolysis in animal tissues. If oxygen is available pyruvate is oxidized via the Krebs Cycle, q.v. /20/ End of fermentation plant tissue. /21/ Uridine diphosphate glucose required as coenzyme. /22/ Inhibited by iodoacetate.

213. PATHWAYS OF LIPID METABOLISM: MAMMALS

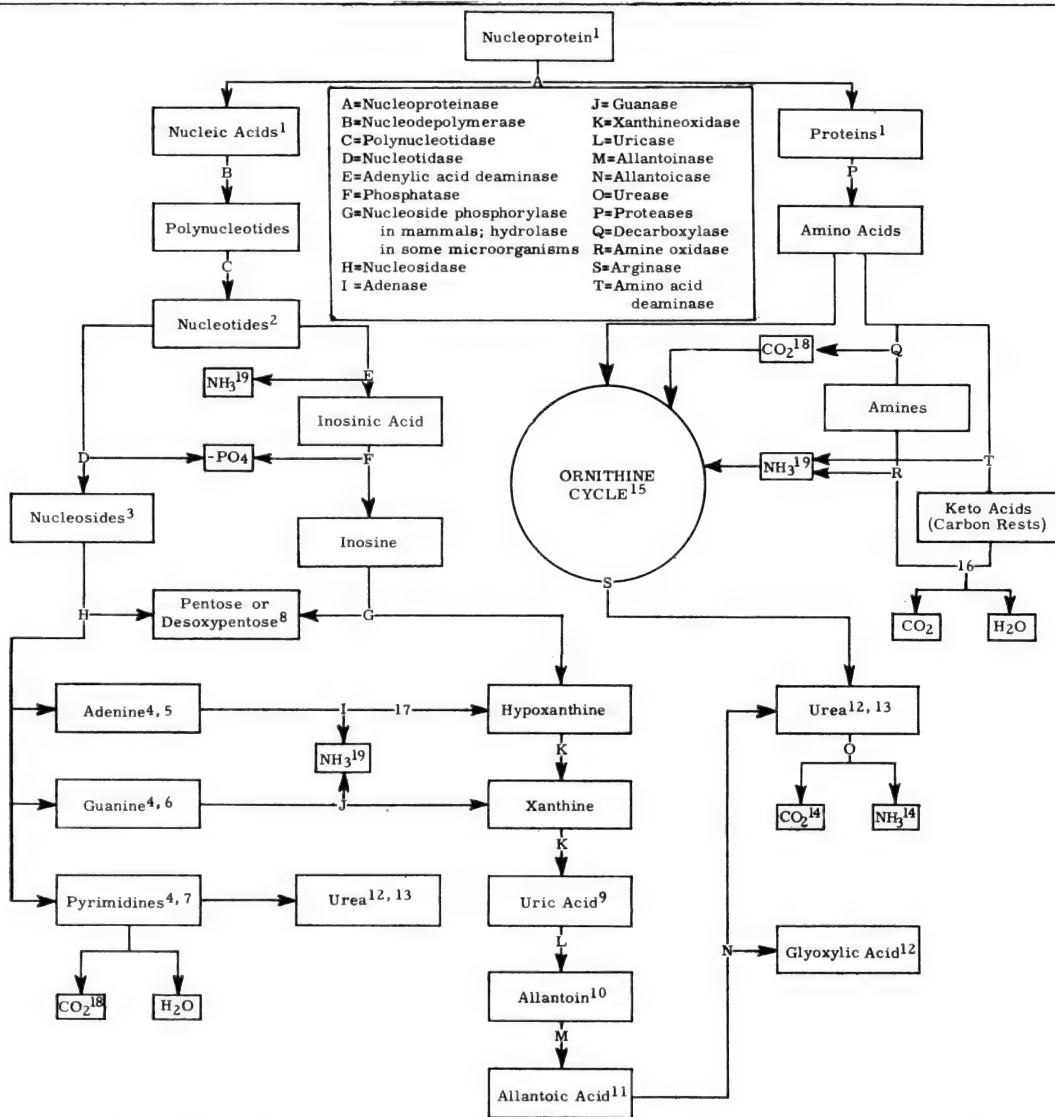
These pathways are believed to occur in the lipid metabolism of animal forms in general. They are based on studies confined chiefly to mammals.



/1/ In intestinal lumen, blood, liver, other tissues. /2/ In chyle. /3/ Some absorption by intestinal mucosa. /4/ Formed in intestinal mucosa, or absorbed from lumen, pass into chyle, short chains possibly also into portal blood. /5/ Digestion in intestinal lumen. /6/ Probably transitory in tissues. /7/ In intestinal mucosa, liver, other tissues. /8/ Occur free (ionized) in intestinal lumen, blood, liver; free existence in chyle, questioned; free existence probably transitory in other tissues, if it occurs. /9/ In liver, carbon chains lengthened or shortened (cf Fn 20), and H added to C₉-10, or removed creating double bonds. /10/ Chiefly (?) unsaturated. /11/ Synthesis probably in intestinal mucosa, liver, blood. /12/ In chyle, blood, and small amounts in liver, other tissues; not in brain, red cells. /13/ Chiefly lecithin, cephalins (phosphatides of ethanolamine, serine, inositol, acetal, and polyglyceride phosphatides) some sphingomyelin. /14/ In intestinal mucosa, liver (?), other tissues (?). Split to choline, glycerol, phosphoric acid. /15/ In intestinal lumen, absorbed by intestinal mucosa, where resynthesized into glycerides, including phospholipids. Metabolized to pyruvate. /16/ In liver, other tissues. /17/ Fatty acid ester of coenzyme A, i.e., acyl~CoA ester, formed by ATP-dependent acylation of CoA or by transfer of CoA from succinyl- or other CoA ester. /18/ Coenzyme A probably = pantotheine (pantoic acid + β-alanine + thioethanolamine) + ADP, with a third PO₄ at C₃ of the ribose; forms fatty acid thiol esters via the SH in the thioethanolamine. /19/ Reverse of β-oxidation (cf Fn 20). Retarded or blocked in diabetes mellitus, starvation (?). Insulin useful, probably necessary, but site of lipogenic action not known -- possibly the hexokinase reaction in carbohydrate metabolism. /20/ Fatty acid~CoA ester shortened 2 carbons at a time by β-oxidation, breaking off a molecule of acetyl~CoA at each step, and re-esterifying the remainder with CoA. /21/ Acetic acid ester of coenzyme A known also as S-acetyl coenzyme A, active acetyl. /22/ Via squalene (?). /23/ Adrenal steroids (C₁₁oxy) promote synthesis (?). /24/ Hormones, bile acids. /25/ Acetyl~CoA → Acetoacetyl~CoA → Acetoacetate. Transported from liver via blood to other tissues, where oxidized, via acetyl~CoA and Krebs Cycle, to CO₂ and H₂O. Some conversion to acetone. /26/ Coprosterol, epicoprosterol excreted. /27/ Tyrosine, leucine, isoleucine also converted directly to acetoacetate. /28/ Aspartate enters Krebs Cycle not via pyruvate, but by conversion directly to oxalacetate. /29/ Occurs in blood, liver, muscle, other tissues. /30/ Occurs in muscle, especially in exercise, the lactate diffusing into the blood stream. /31/ Occurs in liver, muscle, brain, other tissues. /32/ ATP-dependent reaction with CoA. /33/ Diphosphothiamine (= cocarboxylase), lipoic acid, Mg⁺⁺ required. /34/ Pyruvate + CO₂ → oxalacetate, malate, components of Krebs Cycle. Oxalacetate condenses with acetyl~CoA, to form citrate. This removal of acetyl~CoA by oxalacetate (i.e., by pyruvate), occurring when acetyl~CoA is being formed in active fat catabolism, may explain antiketogenic action of carbohydrate (and protein). /35/ And energy liberation.

214. PATHWAYS OF NUCLEOPROTEIN CATABOLISM

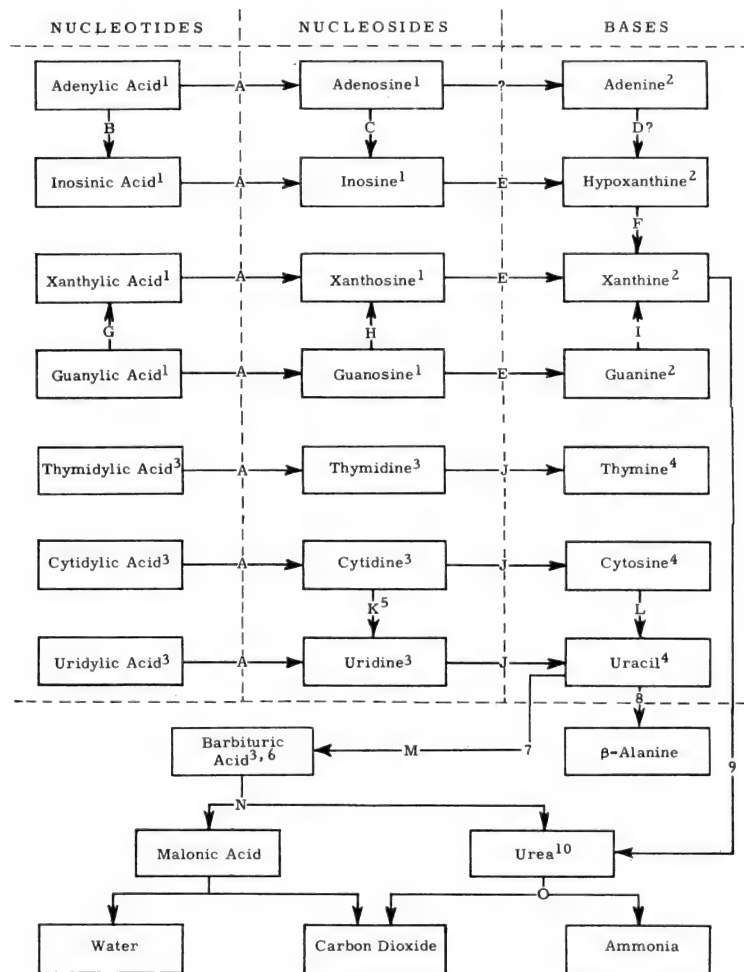
Nucleoproteins generally are composed of basic proteins, histones or protamins, associated with nucleic acids. The nucleic acids are complex molecules, each composed of many nucleotide units, joined by phosphate sugar linkages. Each nucleotide is made up of a purine or pyrimidine base, linked to a pentose or deoxypentose, and this in turn to a molecule of phosphoric acid. Upon hydrolysis of the nucleotide in the digestive tract or tissues, the phosphoric acid is removed. The remaining compound, a nucleoside, contains the purine or pyrimidine base and the sugar residue.



/1/ Catabolism of nucleoprotein, nucleic acid, and protein may take place in the alimentary canal or in the tissues. See Table 251 for detailed pathways of purine and pyrimidine nucleotide catabolism. /2/ Some intestinal absorption. Nucleotidase in liver splits both pyrimidine and purine nucleotides to nucleosides. /3/ Absorbed in the intestine. Purine nucleosides are split into purines and pentoses by purine nucleosidase present in tissues. /4/ Mammals do not require exogenous purines or pyrimidines, but can synthesize them from products of protein metabolism. /5/ Adenine and guanine are the only naturally occurring purines in nucleic acids. /6/ Excreted by pig and spider. /7/ Little is known about the stages in pyrimidine catabolism. It is thought that pyrimidine nitrogen is largely converted to urea, indicating disruption and metabolism of the pyrimidine ring. /8/ D-ribose and D-2-deoxyribose have been definitely established as present in nucleoproteins, and are degraded via the Warburg-Dickens-Lipmann pathway; other pentoses may be present. /9/ Excreted as end product of purine catabolism by primates, Dalmation dog, some reptiles, some insects; and as end product of catabolism of proteins as well as purines and pyrimidines by birds (no urea formation by birds). /10/ Excreted by most mammals, gastropods, and some insects. /11/ Excreted by some teleost fishes. /12/ Excreted by most fishes, amphibia, fresh-water lamellibranchs. /13/ Urea is excreted as the end product of amino acid metabolism by mammals, and as an end product of purine (and pyrimidine?) metabolism by some other forms. /14/ Crustacea, geophyean worms, marine lamellibranchs do not excrete urea but break it down to CO₂ and NH₃ which are excreted. /15/ Urea formation in the mammalian liver is via the "Ornithine Cycle" (Krebs-Henseleit Cycle). The pathway through the cycle is: ornithine → citrulline → arginine succinate → arginine → ornithine. CO₂ and NH₃ enter the cycle via carbamyl glutamic acid at ornithine; NH₃ enters the cycle via aspartic acid at citrulline. Arginine succinate is split to arginine and fumaric acid, after which arginine is converted to ornithine with the release of urea. /16/ Via Krebs Cycle. In the course of amino acid metabolism, previous to entry into the Krebs Cycle, sulfur-containing amino acids lose their sulfur -- usually in the form of SO₄. /17/ There is little likelihood that the route adenine → hypoxanthine is of any importance in animals. Adenase is not found to any extent in mammals. /18/ May enter into metabolic processes, into the Ornithine Cycle and be incorporated into and excreted as urea, or be excreted as such. /19/ NH₃, as in the case of CO₂, is also used to synthesize many tissue constituents. Hence, it may enter into metabolic processes, be built into amino acids, incorporated into urea and excreted, or excreted as such across the kidney tubule (in appropriate animal species).

215. PATHWAYS OF PURINE AND PYRIMIDINE NUCLEOTIDE CATABOLISM

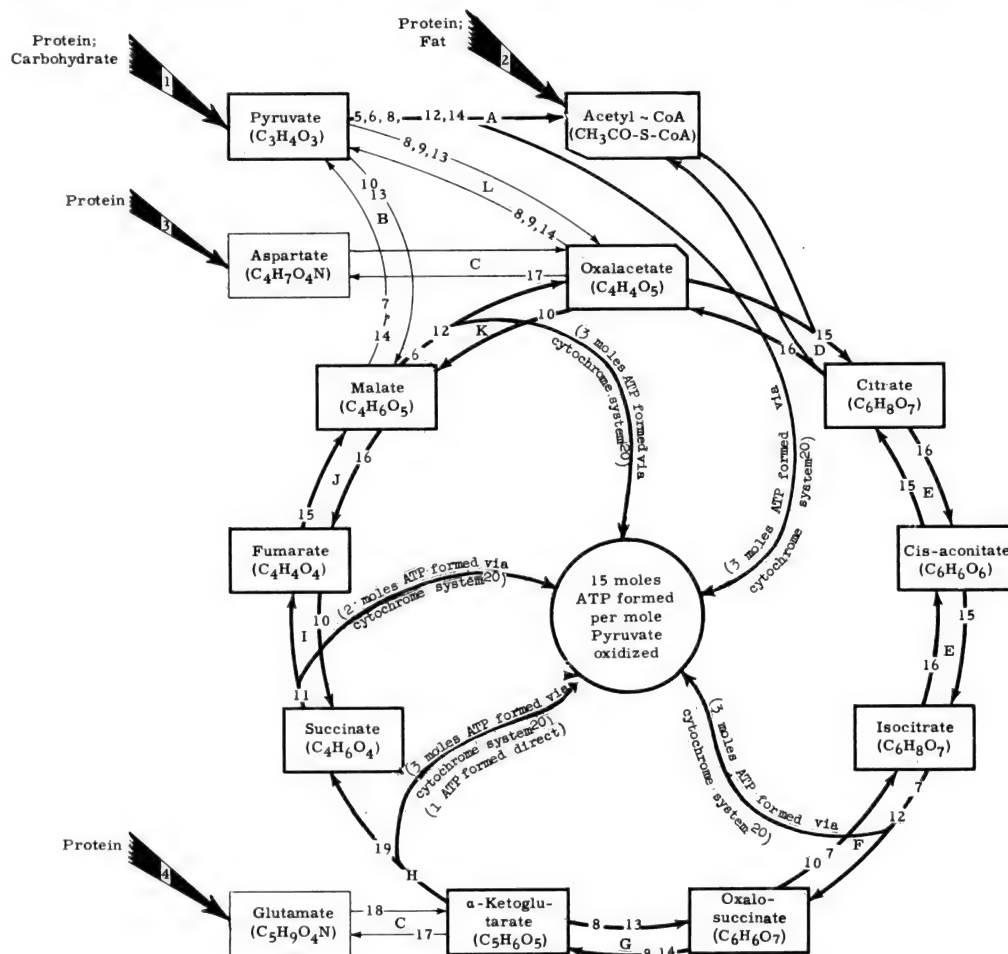
Nucleotides are composed of a purine or pyrimidine base linked to a pentose or desoxypentose sugar which, in turn, is linked to phosphate. Removal of the phosphate leaves a compound designated as a nucleoside. See Table 252 for pathways of nucleoprotein catabolism in general.
A = Phosphatase; B = Adenylic acid deaminase; C = Adenosine deaminase; D = Adenase(?); E = Nucleoside phosphorylase; F = Xanthine oxidase; G = Guanylic acid deaminase; H = Guanosine deaminase; I = Guanase; J = Phosphorylase or hydrolase; K = Cytidine deaminase; L = Cytosine deaminase; M = Uracil-thymine oxidase; N = Barbiturase; O = Urease.



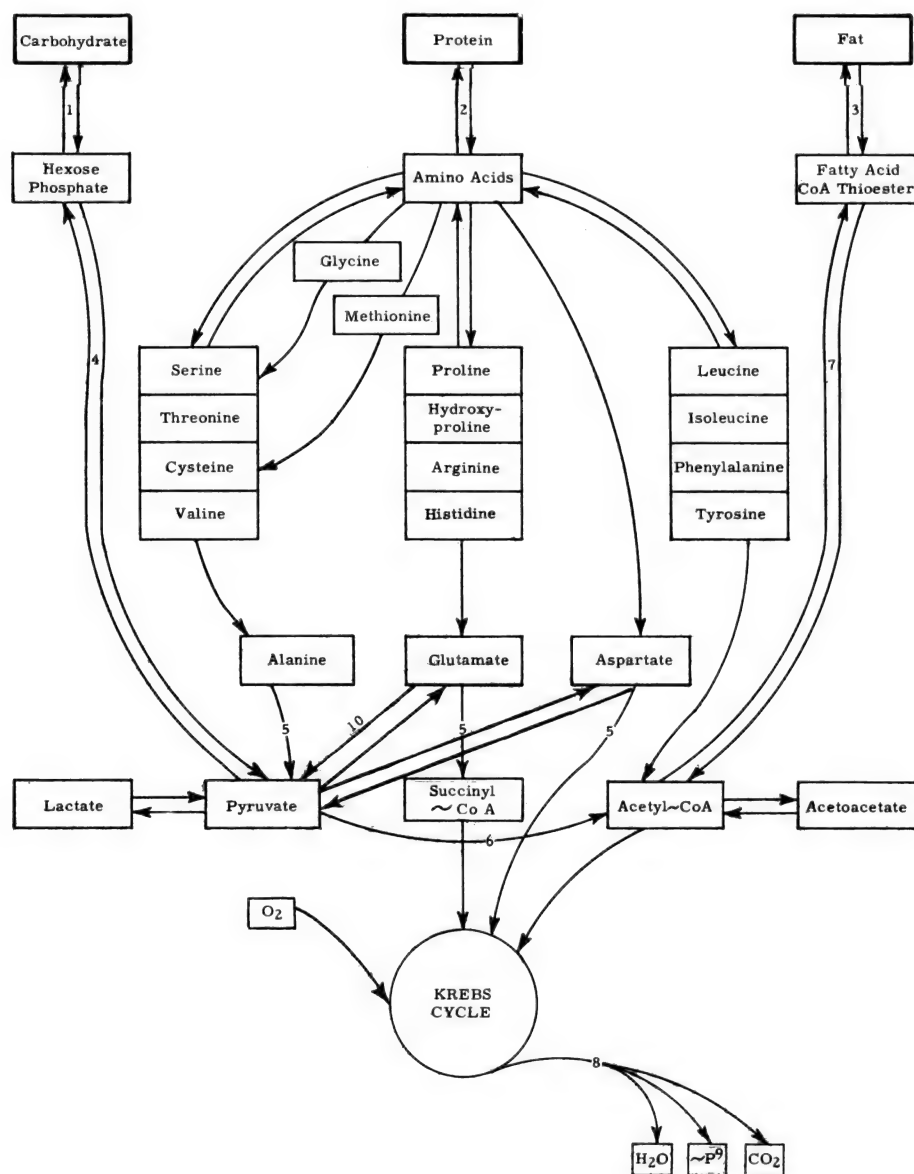
/1/ A purine derivative or contains purine ring. /2/ A purine. /3/ A pyrimidine derivative or contains pyrimidine ring. /4/ A pyrimidine.
/5/ Demonstrated in yeast and *Escherichia coli*. /6/ Thymine yields 5-methyl barbituric acid. /7/ Pathway demonstrated with *Corynebacterium* and *Mycobacterium*. /8/ In animal tissues; methyl uracil (thymine) yields β-aminoisobutyric acid. /9/ Via: uric acid, allantoinic acid, and glyoxylic acid. /10/ Urea is excreted as the end product of amino acid metabolism by mammals, and as an end product of purine and pyrimidine metabolism by most fishes, amphibia and fresh-water lamellibranchs.

The Krebs Cycle (tricarboxylic acid cycle) is a major pathway for the final aerobic oxidation of carbohydrates, fats, and proteins. These three nutrients are channeled into the cycle via their two key metabolites, pyruvate and acetyl-CoA ("active acetate"). Each "revolution" of the cycle oxidizes acetate to CO_2 and H_2O . One mole (59 g) of acetate thus oxidized releases approximately 200 kilocalories of energy. A portion of the released energy (approximately 144 kilocalories) enters the phosphate pool as ATP. Twelve moles of ATP are formed from ADP and PO_4 (by energizing PO_4 to PO_4). The remainder of the released energy appears as heat. Oxidation of 1 mole (87 g) of pyruvate, proceeding via acetyl-CoA, contributes a total of 14 moles of ATP to the energy pool.

A=Pyruvic decarboxylase; B=Malic enzyme; C=Transaminase; D=Condensing enzyme; E=Aconitase; F=Isocitric dehydrogenase; G=Oxalosuccinic carboxylase; H= α -Ketoglutaric dehydrogenase; I=Succinic dehydrogenase; J=Fumarase; K=Malic dehydrogenase; L=Oxalacetic decarboxylase.



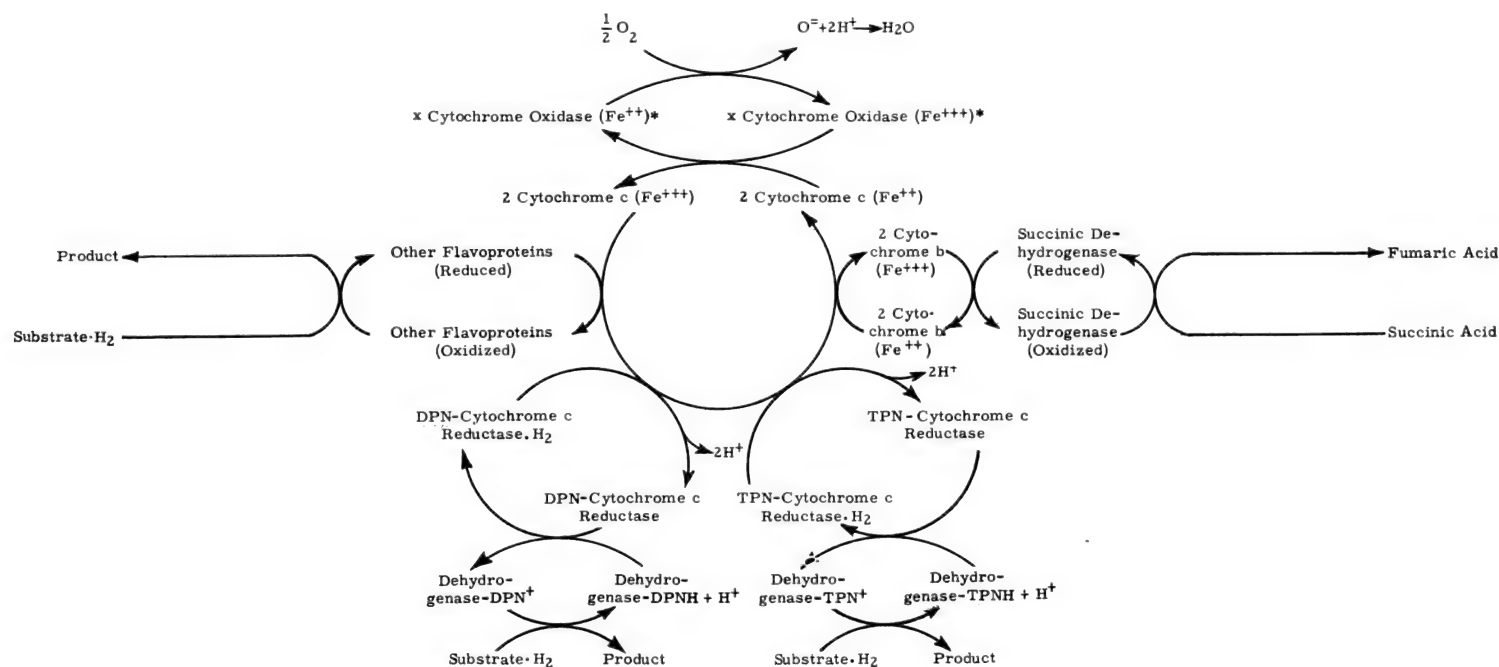
/1/ Glucogenic amino acid precursors for pyruvate are: alanine, glycine, serine, threonine, methionine, cysteine, valine. /2/ Ketogenic amino acid precursors for acetyl-CoA are: leucine, isoleucine, phenylalanine, tyrosine. /3/ Aspartic acid occurs as a component of protein. /4/ Glutamic acid occurs as a component of protein or may be formed from: arginine, proline, hydroxyproline, histidine, ornithine. /5/ Coenzyme-A (=ATP-pantoyl- β -alanyl-thioethanolamine) and α -lipoic acid required. /6/ In the oxidative direction, DPN (=diphosphopyridine nucleotide, a compound of nicotinamide, D-ribose, H_3PO_4 and adenine; also known as coenzyme I) acts as hydrogen acceptor; in the reverse direction DPNH₂ is hydrogen donor. /7/ In the oxidative direction, TPN (=triphosphopyridine nucleotide; coenzyme II) acts as hydrogen acceptor; in the reverse direction TPNH₂ is hydrogen donor. /8/ DPT (=diphosphothiamine; thiamine pyrophosphate; cocarboxylase) required as coenzyme for the carboxylase (A); also Mg^{++} or Mn^{++} is required as activator for the enzyme. /9/ Biotin required as coenzyme for decarboxylation. /10/ 2H enters into the reaction. /11/ 2H released and their electrons transferred to cytochrome. /12/ Hydrogen ions transferred to DPN (or, in the case of isocitrate \rightarrow oxalosuccinate, to TPN) and pass in turn to flavoprotein, cytochrome-c, cytochrome oxidase, and finally to combination with molecular oxygen. For each H thus passed and finally oxidized, 1.5 moles of ATP are formed by the addition of energized phosphate (PO_4) to ADP. /13/ CO_2 enters into the reaction. /14/ CO_2 released. /15/ H_2O enters into the reaction. /16/ H_2O released. /17/ NH_3 enters into the reaction by transamination. /18/ NH_3 transferred from glutamate by transamination, then enters into Krebs Cycle via α -ketoglutarate. /19/ Footnotes 5, 6, 8, 12, 14 apply to this reaction. /20/ For details, see table on cytochrome system.



/1/ Phosphorylase and PO_4 phosphorylate hexose units in stored polysaccharides; hexokinase and ATP phosphorylate hexoses. /2/ Proteolysis by proteases in digestive tract or tissues. Synthesis by proteases of tissues. /3/ Lipase splits fat into fatty acids and glycerol; glycerol, via glycerol phosphate and dihydroxyacetone phosphate, enters the glycolytic cycle. Fatty acid then is acted upon by coenzyme A. /4/ Glycolysis. /5/ Oxidative deamination. /6/ Oxidative decarboxylation. /7/ β -oxidation. /8/ Chain of electron-transmitting enzymes. /9/ "High energy" phosphorus. /10/ Transamination.

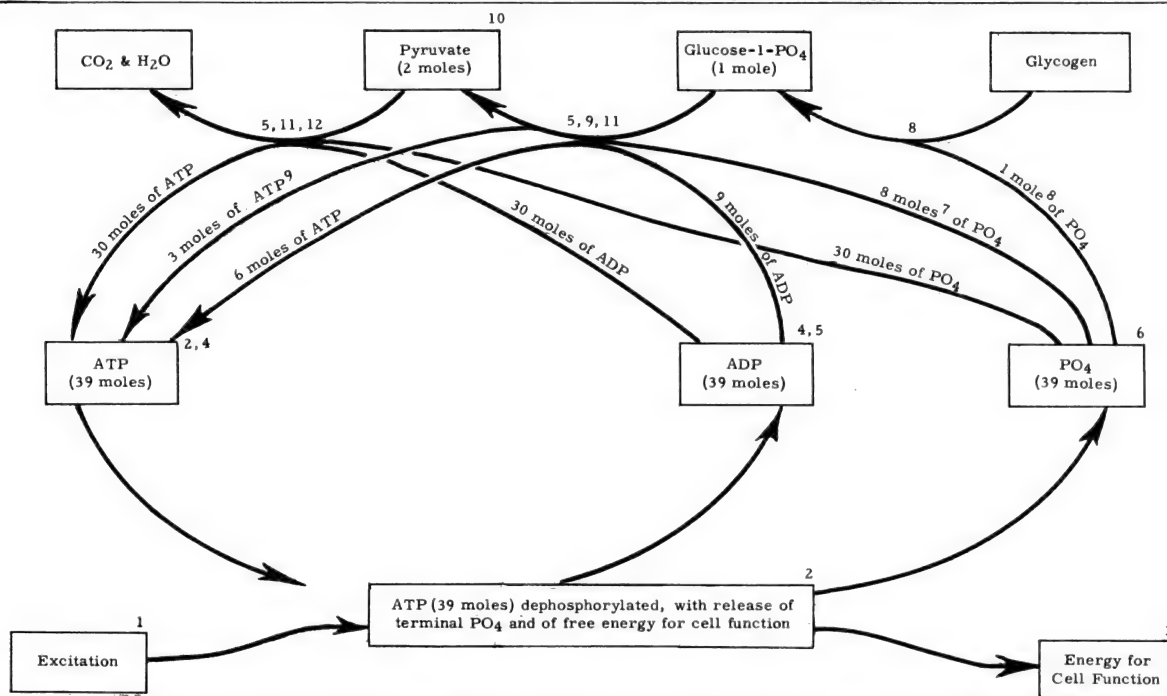
218. THE CYTOCHROME SYSTEM

The cytochromes (iron-containing compounds) in association with certain other compounds constitute the "Cytochrome System." The system operates as the final pathway by which an intermediate metabolite ("substrate"), under the influence of its specific dehydrogenase, releases hydrogen to the first member in a series of carriers for ultimate combination with oxygen to form water. Each step in the process involves both oxidation and reduction: The cytochrome system oxidizes the hydrogen of the substrate by removing electrons from it, thereby producing oxidized substrate and hydrogen ions, and the system itself is reduced in the process and is finally oxidized by molecular oxygen. For each gram of hydrogen thus passed and finally oxidized enough energy is produced to form 1.5 moles of ATP from ADP and PO_4 .



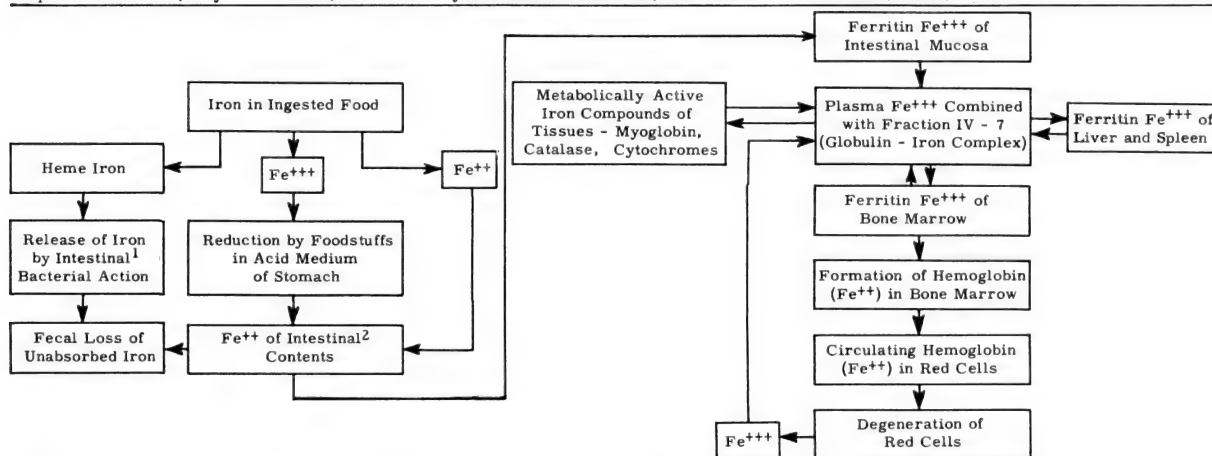
*Cytochrome a and cytochrome a_3 have not been proved to be separate enzymes. For the present, therefore, there is only one enzyme that acts between cytochrome c and molecular oxygen. This component is termed cytochrome oxidase.

Excitation of the muscle (cell) is accompanied by reversal of polarity of the cell membrane. The first identifiable metabolic event to follow is dephosphorylation of ATP. The breaking off of the terminal PO_4 of ATP is accompanied by release of energy previously stored in the molecule. The compound, minus one phosphate, is left as ADP. This compound can accept phosphate and again form ATP. If the presence of such acceptor is viewed as the stimulus to the subsequent steps in activity-metabolism, the presence of ADP causes progression of glucose-1- PO_4 to pyruvate (or to lactate if DPNH has accumulated as a result of O_2 inadequacy), and also brings about the progression of pyruvate to CO_2 and H_2O . In so doing, ADP is reconverted to ATP, (and other phosphate-acceptors that may be present are similarly rephosphorylated). The stimulus to extra release of energy from carbohydrate stores thus disappears, and the cell returns to its basal state of respiration and energy release.



/1/ "When the stimulus is withdrawn, respiration continues at the elevated rate only until the organ is restored to its original state....With no compounds remaining in the unphosphorylated state, the respiration machinery stops with the various enzymes blocked in the acylated and/or phosphorylated states." /2/ The quantity of ATP assumed, 39 moles, is adjusted to the catabolism of 1 mole of glucose-1-PO₄ or 1 mole of 6-carbon unit, component of glycogen. /3/ Approximately 10 kilocalories (a compromise figure; values of 7-12 have been reported recently) of free energy per mole of ATP converted to ADP, or about 400 kilocalories for the quantities represented in the diagram. Energy used for muscle contraction, and for synthesis. /4/ Other high energy carriers than ATP (adenosine triphosphate) and other phosphate acceptors than ADP (adenosine diphosphate) may also function (e.g., creatine phosphate and creatine-- also phosphates of guanosine, cytidine and uridine). /5/ Rate of energy release from stored carbohydrate probably controlled by concentration of phosphate acceptors capable of forming high energy carriers (cf Fn 4). /6/ In inorganic phosphate pool. /7/ These 8 moles include 2 that combine with 2 moles of D-glyceraldehyde-3-phosphate (= "substrate phosphorylation") and are then transferred to ADP; and 6 that combine directly with ADP in association with the oxidation of hydrogen previously released by D-glyceraldehyde-3-phosphate to DPN (to form DPNH = "electron transport phosphorylation"). /8/ One PO₄ combines with one 6-carbon unit in glycogen to form glucose-1-PO₄, with no appreciable energy change. /9/ Not shown in diagram: One mole of ATP is required at an early step in the reaction glucose-1-PO₄ → pyruvate, and 4 moles of ATP are formed at later steps. The net gain is 3 moles of ATP. The 3 moles of PO₄ have come from the 1 mole combined into glucose-1-phosphate (cf Fn 8) and 2 of the 8 moles covered by Fn 7. /10/ Pyruvate is converted to lactate by reaction with DPNH, if the latter has accumulated, as in conditions of relative oxygen deficiency. /11/ Energy from carbohydrate metabolites is built into the ATP molecule. /12/ Via Krebs Cycle.

Adapted from Walker, Boyd and Asimov, "Biochemistry and Human Metabolism," Baltimore: Williams and Wilkins, 1952.

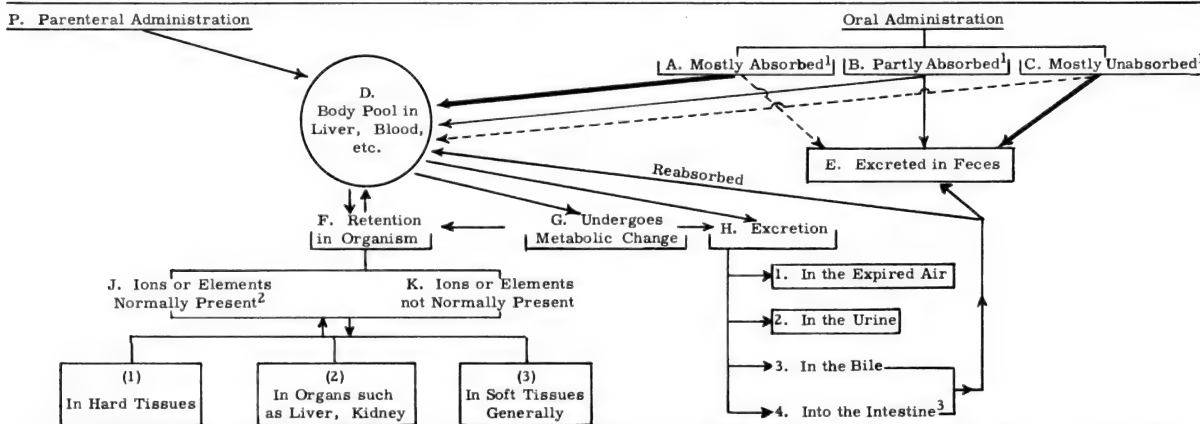


/1/ Large intestine. /2/ Small intestine.

221. PATHWAYS OF MINERAL METABOLISM: MAMMALS

The system of letters and numbers used in this table traces the course(s) of various ions through the diagram. The classifications as to extent of absorption are in general as follows: A, more than 70%; B, 5-70%; C, less than 5%. Underscoring indicates radioactive elements, or that data were obtained, at least in part, from studies using radioactive isotopes. Plus signs (+) indicate valence states to which the data apply. Observations were made on a wide variety of mammalian species. As far as possible, "Other Known Pathways" are listed in order of decreasing importance. Tissue predilections are also listed in this order. There are instances in which different isotopes of the same element show different predilections, but there is usually no difference in their absorption or route of excretion. In some cases an insufficient amount of the ion is absorbed from the alimentary tract to permit a study of its metabolism. In these cases the results of parenteral administration are shown, if available; in other instances less important alternatives to the primary oral pathways are shown. The term "Soft Tissues Generally" refers primarily to muscle, skin, and extracellular fluids.

Part I: PATHWAY DIAGRAM



/1/ This classification is obviously rather arbitrary, since extent of absorption may depend on the amount offered; for example, the absorption of physiologically essential elements may be nearly complete when fed at or near the level of minimum requirement. It is assumed that the various ions are offered in the form of simple soluble compounds, or metallic oxides. /2/ This group includes some trace elements with no known function. /3/ Other than in the bile, or by route not definitely established.

Part II: INDIVIDUAL CATIONS

Information inadequate for classification, but probably poorly absorbed¹: actinium, berkelium, californium, iridium, osmium, rare earth elements not mentioned below, rhodium, tantalum, and technetium.

Element	Primary (Oral) Pathways ²	Other Known Pathways	Element	Primary (Oral) Pathways ²	Other Known Pathways
1 Aluminum	CE	PDH2, PDH3, PDFJ(2)	30 Niobium	CE	PDH2, PDFK(3)
2 Americium	CE	PDH4, PDFK(2, 1), PDH2	31 Palladium	Probably CE ²	PDH2, PDFK(2, 1), PDH4
3 Antimony ⁺⁺⁺	BE, BDH2	PDFK(2, 3), PDH4	32 Platinum	Probably CE ²	PDH2, PDFK(2), PDH4
4 Arsenic ⁺⁺⁺	BE, BDH2	BDFK(2, 3), BDH4	33 Plutonium	CE	PDFK(1, 2), PDH4, PDH2
5 Barium	BE, BDH4	BDFK(1), BDH2	34 Polonium	CE	PDFK(2, 1, 3), PDH4, PDH2
6 Beryllium	CE	PDFK(3, 2, 1), PDH2, PDH4	35 Potassium	ADH2	ADFK(3, 2), ADH3, ADH4
7 Bismuth ⁺⁺⁺	CE	PDH2, PDFK(1, 2, 3), PDH4	36 Praesodymium	CE	PDFK(1, 2), PDH3, PDH4
8 Cadmium	CE	PDFK(2), PDH4, PDH2	37 Promethium	CE	PDFK(1, 2), PDH3, PDH4
9 Calcium	BE, BDFJ(1)	BDH3, BDH4, BDH2, BDFJ(3)	38 Protactinium	Probably CE ²	PDFK(1)
10 Cerium	CE	PDH3, PDH4, PDFK(1, 2)	39 Radium D	Probably BE, BDH2 ²	PDH2, PDH4, PDFK(1)
11 Cesium	ADH2	ADH3, ADH4, ADFJ(3)	40 Radium	BE, BDFK(1, 2)	BDH4, BDH2
12 Cobalt ⁺⁺	BE, BDH2	BDH3, BDH4, BDFJ(2)	41 Rubidium	ADH2	ADFK(3, 2), ADH3
13 Copper ⁺⁺	BE, BDH2	BDH3, BDFJ(2)	42 Ruthenium	CE	PDFK(2)
14 Curium	Probably CE ²	PDFK(1, 2), PDH4, PDH2	43 Samarium	CE	PDFK(1, 2), PDH3
15 Francium	Probably ADH2 ²	PDFK(2, 3)	44 Scandium	Probably CE ²	CDH2, CDFJ(1, 3)
16 Gallium	CE	PDH2, PDFK(1, 2), PDH4	45 Selenium ⁺⁺⁺⁺	ADH2	ADGH1, ADFK(2, 3)
17 Germanium	ADH2	ADH4	46 Silver	CE	PDH3, PDFK(2, 3), PDH2, CDGFK ⁴
18 Gold ⁺⁺	CE	PDFK(2), PDH2, PDH4	47 Sodium	ADH2	ADFK(3, 1, 2), ADH3, ADH4
19 Indium	ADH2	PDH4, PDFJ(2)	48 Strontium	BE, BDFK(1)	BDH2, BDH4
20 Iron ⁺⁺	CE	PDH2, PDH3, PDFK(2, 1)	49 Tellurium ⁺⁺⁺⁺	BE, BDH2	BDGH3, BDGH1, BDGFK(2)
21 Lanthanum	CE	PDFK(1, 2), PDH2	50 Thallium ⁺	ADH2	ADH4, ADFK(2, 3)
22 Lead ⁺⁺	BE, BDH3	ADH4, ADFJ(3, 2)	51 Thulium	CE	PDFK(1, 2), PDH2
23 Lithium	ADH2	BDH3, BDFJ(1, 2, 3)	52 Tin ⁺⁺	BE, BDH2	BDFJ(2, 3), BDH4
24 Magnesium	BE, BDH2	PDH3, PDH4, PDFJ(2, 3)	53 Titanium	Probably CE ²	CDFJ(2)
25 Manganese ⁺⁺	CE	BDFK(2, 3), BDH3, BDH4	54 Uranium ⁺⁺⁺⁺⁺	BE, BDH2	BDFK(2, 1)
26 Mercury ⁺⁺	BE, BDH2	PDH4, PDFK(2, 1)	55 Yttrium	CE	PDFK(1, 2), PDH2, PDH4
27 Neodymium	Probably CE ²	PDFK(1)	56 Zinc	CE	CDFJ(2, 3), CDH3, CDH4, CDH2
28 Neptunium	CE	BDH4, BDFJ(2)	57 Zirconium	CE	PDFK(1)
29 Nickel ⁺⁺	BE, BDH2				

/1/ As would be judged from its position in the periodic table, or on solubility at neutral pH values. /2/ Cations absorbed orally may be assumed to follow the same pathways when given parenterally. /3/ Administered as a soluble complex. /4/ Skin.

Part III: INDIVIDUAL ANIONS

Information inadequate for classification: cyanate, ferricyanide, periodate.

Element	Primary (Oral) Pathways ¹	Other Known Pathways	Element	Primary (Oral) Pathways ¹	Other Known Pathways
1 Bicarbonate	ADH1, ADH2, ADH3	ADH4, ADFJ(all tissues)	16 Nitrite	ADG(to nitrate)	
2 Borate	ADH2		17 Oxalate	ADH2	
3 Bromate	ADH2	ADG(to bromide)	18 Perchlorate	ADH2	
4 Bromide	ADH2	ADH3, ADH4, ADFK(3, 1, 2)	19 Permanganate	CE(reduced to MnO ₂)	
5 Chlorate	ADH2		20 Perrhenate	Probably CE ²	PDH2, PDFK(2)
6 Chloride	ADH2	ADH3, ADH4, ADFJ(3, 1, 2)	21 Persulfate	ADG(to sulfate)	
7 Chromate	ADH2	ADH4, ADGH2, ADGH3, ADGFK(2)	22 Phosphate	BE, BDH2	BDFJ(1, 2, 3)BDH3, BDH4
8 Cyanide	ADH2	ADH1, ADG(to SCN ⁻)	23 Silicate	BE, BDH2	BDFJ(2)
9 Ferrocyanide	ADH2		24 Sulfate	BE, BDH2	BDH3, BDH4
10 Fluoride	ADH2	ADFKJ(1, 3), ADH4	25 Sulfide	ADG(to sulfate)	ADH1
11 Hypophosphite	ADH2		26 Thiocyanate	ADH2	ADFK(3), ADH3, ADH4
12 Iodate	ADG(to iodide)		27 Thiosulfate	BE, BDG(to sulfate)	
13 Iodide	ADH2	ADFKJ(3, 2), ADH3	28 Tungstate	BE, BDH2	BDFK(1, 2)
14 Molybdate	ADH2	ADH4, ADFJ(1, 2)	29 Vanadate	ADH2	ADFKJ(2), ADH4
15 Nitrate	ADH2	ADG, ADFK(3)			

/1/ Anions absorbed orally may be assumed to follow the same pathways when given parenterally. /2/ As would be judged from its position in the periodic table, or on solubility at neutral pH values.

222. EXCRETION PRODUCTS: MAN

Values, widely variable with changes in diet, are based on "normal" dietary intake, including approximately 10 grams of nitrogen per day. Values are per kilogram of body weight per day and are expressed as milligrams unless otherwise noted. Values in parentheses are ranges and conform with estimate "d" of the 95% range (cf Introduction).

Constituent	Excreted in Urine	Excreted in Feces	Constituent	Excreted in Urine	Excreted in Feces
1 Water, total	17,000(7,800-27,500)	(910-1820)	80 Nitrates, µg	7140	
2 Solids, total	860(780-1000)	394(140-560)	81 Phosphorus	15(10-19)	9.86(7.1-20)
3 Nitrogen, total ^{1,2}	160(112-268)	24(11.4-36.0)	82 Potassium	34(14-46)	6.7
4 Protein nitrogen	(0.0046-0.018)		83 Selenium, µg	1.0(0.0-3.3)	
5 Amino acid nitrogen	2.5(2.2-4.4)		84 Silicon, µg	108(14-200)	
6 Ammonia nitrogen	9.2(4.0-18.2)	(0.36-1.2)	85 Silver, µg		0.8
Principal N-Containing Constituents			86 Sodium	46(38-91)	1.7
7 Creatinine	15(12-25)		87 Sulfur, total	16.5(4-40)	2.0
8 Hippuric acid	8(1-12)		88 Sulfur, ethereal	1.0(0.6-4.3)	
9 Urea	300(215-500)		89 Sulfur, inorganic	12.5(3.5-18.25)	
10 Uric acid	9(5-12)		90 Sulfur, neutral	1.9(1.0-3.0)	
Amino Acids			91 Tin, µg	(0.13-0.31)	(170-450)
11 Alanine, total	0.55		92 Zinc, µg	18(11-33)	100(58-144)
12 Arginine, free	0.31(0.15-0.5)		Hormones		
13 Arginine, combined	0.1(0.0-0.2)		93 Androgens, µg	(30-100)	
14 Arginine, total	0.4(0.34-0.5)	3.8(2.9-5.0)	94 Epinephrine, µg	0.16(0.07-0.31)	
15 Aspartic acid, free	0.02(0.014-0.26)		95 Estrogens, µg	(0.1-0.5)	
16 Aspartic acid, combined	2.3(1.2-3.7)		96 Formaldehydogenic		
17 Aspartic acid, total	2.32(0.37-3.7)		steroids, µg	(3-140)	
18 Citrulline, free ³	0.58(0.26-0.7)		97 17-Ketosteroids, µg	♂ 160, ♀ 100	
19 Citrulline, total	(0.345-0.79)		98 Oxytocicosteroids, µg	(1.0-6.0)	
20 Cystine, free	1.3(0.65-2.0)		99 Noradrenaline, µg	0.41(0.18-0.9)	
21 Cystine, total	(1.5-2.4)		Lipids		
22 Glutamic acid, free	0.52(0.0-1.07)		100 Cholesterol, total	(0.0-0.007)	8(10-20) ⁵
23 Glutamic acid, combined	4.5(1.0-10.0)		101 Fat, total		56(30-100)
24 Glutamic acid, total	5.27(1.58-11.55)		102 Fat, neutral		(10-45)
25 Glycine, free	10.1(9.0-12.0)		103 Fat, unsaponifiable		33(22-38) ⁶
26 Glycine, total	(2.3-18.0)		104 Fatty acids, total		30(4-64)
27 Histidine, free	2.7(0.94-4.8)		105 Fatty acids, free		16(4-38)
28 Histidine, combined	0.6(0.07-1.8)		106 Soaps		53(40-66) ⁶
29 Histidine, total	3.0(0.98-6.59)	1.7(1.4-2.1)	Organic Acids		
30 Hydroxyproline, total	0.02		107 Citric acid	(3-17)	
31 Isoleucine, free	0.085(0.03-0.3)		108 Creatine ⁷	2.9(1.1-3.86)	
32 Isoleucine, combined	0.2(0.06-0.4)		109 Guanidoacetic acid	(0.23-0.51)	
33 Isoleucine, total	0.3(0.11-0.6)	4.3(3.3-5.5)	110 Formic acid	(0.42-2.0)	
34 Leucine, free	0.14(0.05-0.25)		111 Indoleacetic acid	(0.03-0.06)	
35 Leucine, combined	0.2(0.05-0.4)		112 Lactic acid	40	
36 Leucine, total	0.32(0.20-0.52)	5.6(4.3-6.9)	113 Oxalic acid	0.285(0.23-0.5)	
37 Lysine, free	0.5(0.25-1.13)		114 Phenols	4.0(0.19-6.6)	(0.0-3.0)
38 Lysine, combined	0.6(0.2-1.1)		Pigments		
39 Lysine, total	1.04(0.48-2.0)	5.7(4.5-6.9)	115 Bilirubin, µg	70	
40 Methionine, free	0.11(0.05-0.18)		116 Coproporphyrin I		
41 Methionine, combined	0.03		and III, µg	(0.24-1.4)	
42 Methionine, total	0.14(0.12-0.17)		117 Porphyrins, µg	(0.0-0.4)	
43 Ornithine, free ³	0.15		118 Urobilin, µg	(7-20)	
44 Phenylalanine, free	0.23(0.1-0.43)		119 Urobilinogen, µg	(0.6-3.0)	2.0(0.57-4.0)
45 Phenylalanine, combined	0.1(0.04-0.2)		Vitamins		
46 Phenylalanine, total	0.33(0.21-0.6)		120 Vitamins A, D, K, µg	(0-trace)	
47 Proline, free	0.12(0.05-0.21)		121 Ascorbic acid, µg	380(130-790)	70(60-70)
48 Proline, combined	0.5(0.3-0.8)		122 Biotin, µg	0.4(0.33-0.75)	1.9(0.63-6.64)
49 Proline, total	0.61(0.33-0.9)		123 Carotenes, µg		(20-600) ⁸
50 Serine, free	0.4(0.21-0.52)		124 Choline, µg	90(80-130)	
51 Serine, combined	0.25(0.0-0.5)		125 Cobalamin, µg	0.0004(0.00023-0.00079)	
52 Serine, total	0.65(0.35-1.4)		126 Vitamin E, µg		308(226-391)
53 Threonine, free	0.37(0.17-0.62)		127 Folic acid group, µg	0.2(0.03-0.3)	4.3(1.8-7.7)
54 Threonine, combined	0.4(0.3-0.8)		128 Inositol, µg	170(170-220)	
55 Threonine, total	0.77(0.36-1.2)	4.0(3.3-5.2)	129 Nicotinic acid, µg	(11-105)	52(12-124)
56 Tryptophan, free	0.37(0.12-0.7)		130 N-methyl nicotinamide, µg	130(73-400)	
57 Tryptophan, combined	0.3(0.009-0.4)		131 Pantothenic acid, µg	44(20-100)	31.4(3.85-63.4)
58 Tryptophan, total	0.7(0.23-1.3)		132 Para-aminobenzoic acid, µg	2.11(2.0-3.0)	3.5(1.01-8.2)
59 Tyrosine, free	0.3(0.17-0.55)		133 Pyridoxal, µg	3.0(0.7-5.4)	
60 Tyrosine, combined	0.5(0.08-0.9)		134 Pyridoxamine, µg	1.6(0.3-2.1)	
61 Tyrosine, total	0.79(0.35-1.45)		135 4-Pyridoxic acid, µg	51(9-160)	
62 Valine, free	0.065(0.04-0.125)		136 Riboflavin, µg	14.3(0.2-22.5)	14.7(8.0-23.0)
63 Valine, combined	0.2(0.09-0.4)		137 Thiamine, µg	2.6(0.43-5.6)	7.8(0.67-18.0)
64 Valine, total	0.3(0.21-0.45)	4.6(3.6-6.2)	138 Trigonelline, µg	(30-300)	
Electrolytes and Minor Minerals			Miscellaneous Compounds		
65 Aluminum, µg	(0.7-1.6)	0.6	139 Acetone bodies	0.285(0.03-0.7)	
66 Arsenic, µg	0.46(0.0-1.15)	33(1-116)	140 Allantoin	0.27(0.18-0.36)	
67 Bromine, µg	(12-110)		141 Histamine	(0.2-1.0)	
68 Calcium, µg	2900(1100-4910)	7490(5,000-10,000)	142 Hydroxytyramine, µg	(1.4-2.8)	
69 Chloride	115(84-193)	(0.21-0.5)	143 Imidazole derivatives	(1.35-9.4)	(0.0-0.2)
70 Cobalt, µg	0.07(0.05-0.12)	0.007(0.002-0.02)	144 Indican	0.14(0.06-0.45)	
71 Copper, µg	2.38(0.0-7.52)	27(23-37)	145 Methionine sulfoxide	(0.0-0.31)	
72 Fluoride, µg	(6.7-100) ⁴		146 Purine bases	0.41(0.18-0.92)	(2-3)
73 Iodide, µg	1.4(0.2-2.13)		147 Reducing substances	(7-20)	
74 Iron, µg	0.7(0.7-1.4)	120(65-208)	148 Sugars, as glucose	1.4	
75 Lead, µg	0.5(0.06-2.1)	4.2(2.2-19.8)	149 Taurine	(0.105-0.2)	
76 Magnesium, µg	1850(950-4500)	2500(1510-3185)	150 Volatile acids, total,		2.66(1.61-4.45)
77 Manganese, µg	(0.095-1.4)	(18-120)	ml of 0.1 N		
78 Mercury, µg	(0.007-0.01)	0.14			
79 Nickel, µg	2.1(2.0-4.0)	(1.2-2.5)			

/1/ Present in nitrogen compounds, not as free nitrogen. /2/ Calculated from nitrogen of principal N-containing constituents, plus ammonia- and amino acid nitrogen. /3/ Identity not proven. /4/ Including regions in Texas where dental fluorosis is endemic. /5/ Age 10 mo. /6/ Age 8-12 yr. /7/ Not normally present in urine of adult males. /8/ Carotene and xanthophyll; 8-100 µg/kg body wt/day for xanthophyll alone.

223. EXCRETED NITROGEN, PARTITION: ANIMALS

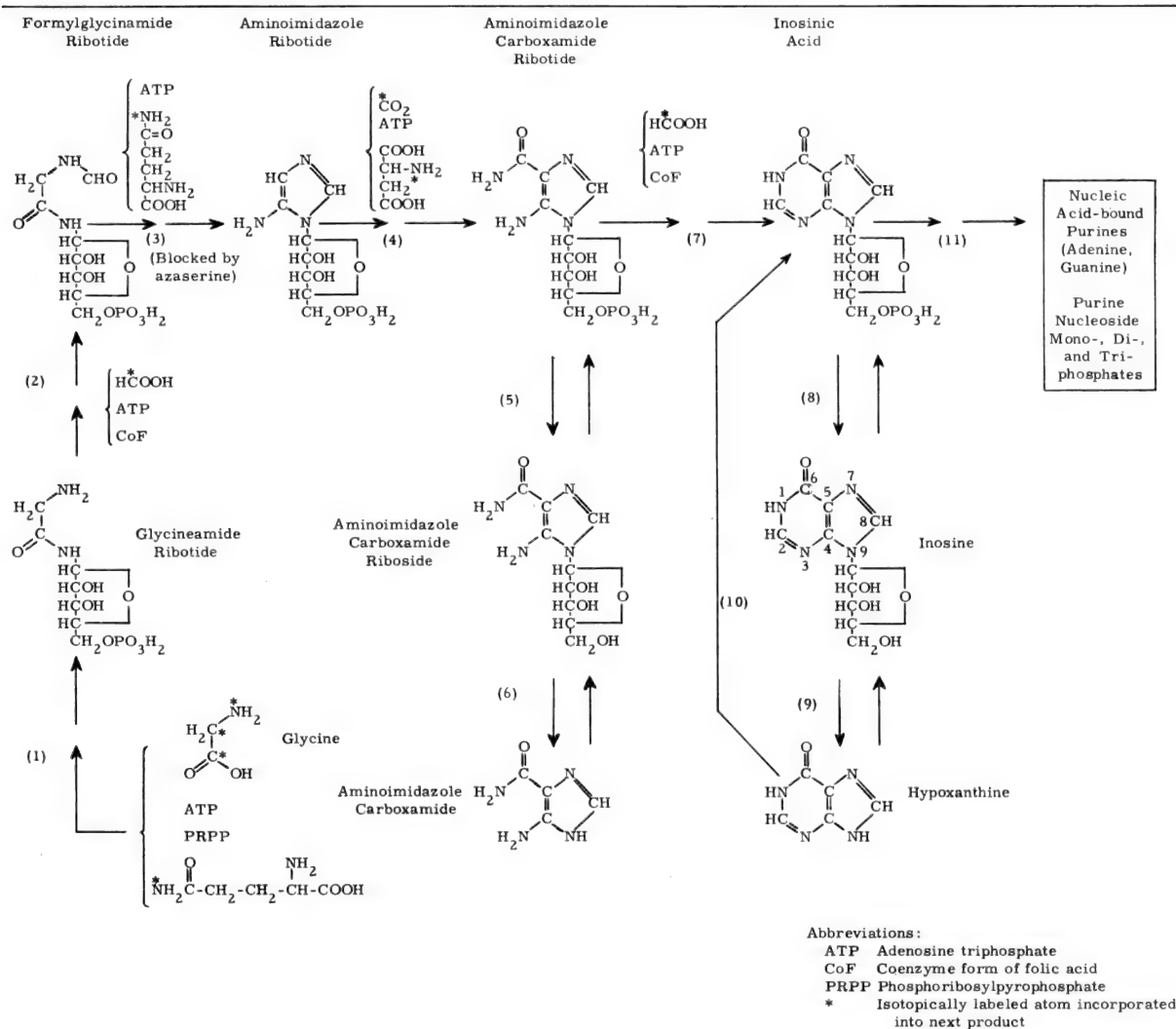
Values are grams of nitrogen per 100 grams of total nitrogen excreted. Values in parentheses are ranges and conform to estimate "d" of the 95% range (cf Introduction).

Species		Allantoin-N	Amino Acid-N	Ammonia-N	Creatine-N and Creatinine-N			Purine-N ¹	Urea-N	Uric Acid-N	Other Specified-N	Unidentified
					Creatine	Creatinine	Combined					
Vertebrata												
1	Mammalia											
2	Man (<i>Homo sapiens</i>)			4.8(3.2-5)		3.6	(3.1-4.9)		87(85-90)	0.65(0.5-1.5)		4(2-6.4)
3	Alpaca (<i>Auchenia vicunna</i>)			4.5	2.7	4.6			60	0.3		28
4	Bat (<i>Xantharpyia</i> spp)		0.96	6		8.5	8.5		63	0.87		20.3
5	Camel (<i>Camelus dromedarius</i>)		(0.2-1.7)	15(12-19)	3.8	14	(17.6-18.1)		44(33-56)	0.3		16.2(13-20)
6	Cat (<i>Felis catus</i>)			(3.9-8.1)		(0.57-1.9)			(72-84)	(0.2-0.22)		
7	Dog (<i>Canis familiaris</i>)			3.5(3.5-28)		0.8	(0.9-10)		91(46-92)			5(1.4-22)
8	Hyena (<i>Hyaena</i> spp)	1.75	0.95	4.0	0.29	0.59	0.88	0.23	89	0.06		2.8
9	Leopard (<i>Panthera pardus</i>)	0.52	0.86	3.2	0.44	0.88	1.32	0.25	87	0.06		
10	Llama (<i>Lama glama</i>)	21.4	1.4(1.3-1.4)	2.0(1.8-2.2)	2.2	8.3	(9.1-11.7)		64(61-68)	0.8		
11	Seal (<i>Phoca vitulina</i>)			(2-7.5)			(9.1-31)		(61-90)	(6-11)		
12	Tiger (<i>Panthera tigris</i>)	1.3	0.95	3.3	0.43	1.29	1.72	0.18	89	0.06		3.4
13	Weasel (<i>Mustela</i> spp)	0.48	0.89		1.37	0.3	1.67	0.58	91	0.16		2.6
14	Whale (<i>Balaenoptera physalus</i>)			(1.9-3.6)		Trace	(0.3-3.8)		(85-93)	3(1.6-4.4)		(2.7-3.1)
15	Aves											
16	Duck (<i>Anas</i> spp)			3.2					4.2	72		20.7
17	Fowl (<i>Gallus domesticus</i>)		6	1.5(1.5-17)		8	(7.4-9.1)	8	0.9(0.9-10)	70(63-87)		28
18	Goose (<i>Anser</i> spp)			13.5					80			6.5
19	Swan (<i>Cygnus</i> spp)			13.8					2.6	69		13.9
20	Reptilia											
21	Alligator (<i>Alligator</i> spp)			(37-81)					(1.3-17)	(7-19.8)		(0.2-23)
22	Lizard (<i>Chalcides ocellatus</i>)	2.7								93		
23	Python (<i>Python</i> spp)		2.3	8.7						89		
24	Snake (<i>Eryx thebaicus</i>)		1.1	5.7		0.23		0.3	63		0.95 ²	29.1
25	Tortoise (<i>Chelonia mydas</i>)	(4.4-25)	(5.4-18.4)	(29-51)	2.6	0.9	(5.2-11.5)		(0-12)	(1.4-6.3)	8-23 ²	(2.4-22)
26	Amphibia											
27	Frog (<i>Rana catesbiana</i>)			(3-38)					(62-88)	(Trace-0.4)		7.5
28	Pisces											
29	Carp (<i>Cyprinus</i> spp)		2.6	(75-77)					(12.5-14.5)			(5.5-12.5)
30	Catfish (<i>Ictalurus furcatus</i>)		20	20			7.9		24.6			16.9
31	Cod (<i>Gadus callarias</i>)		(14.8-21.4)				(53-56)		(6.5-11.2)	(1.7-2.4)		(15.2-19)
32	Flounder (<i>Pseudopleuronectes americanus</i>)		8.9(8.2-9.7)	2.2(1.8-2.6)		20.5	(15-26)		17.3(13-21)	1.2(1.2-1.3)	0.4-1 ³	50(48-51)
33	Goosefish (<i>Lophius piscatorius</i>)		8.4(5.3-15)	0.6(0.3-1.3)		2.6	(24-64)		0.9(0.1-2.7)	0.2(0.2-0.4)	37 ³	(28-63)
34	Lungfish (<i>Protopterus aethiopicus</i>)			41	0.54	6.28			18.5	0.8		
35	Sheepshead (<i>Archosargus probatocephalus</i>)		(15-19.9)	(8.4-9.6)			(15.1-15.5)		(22.9-23)	(6.4-8.4)		(25-26)
Invertebrata												
36	Arthropoda											
37	Amphipod (<i>Gammarus locusta</i>)		(5-8)	(74-91)				(2-4)	(Trace-3)			(3-22)
38	Blowfly, larva (<i>Calliphora</i> spp)			Trace	Trace				Trace	Trace		
39	Crab (<i>Cancer pagurus</i>)		20	43				10	12.9	2.8		11.5(4-11.5)
40	Crayfish (<i>Astacus fluviatilis</i>)		10(5-12)	60(53-65)				4.4(3.2-6.4)	11(10-12)	0.8(0.3-1.2)		14.7
41	Grasshopper (<i>Melanoplus</i> spp)		17.7	3.3					70			
42	Isopod (<i>Oniscus asellus</i>)		(0-12)	(44-50)				(14-38)	8.7	(4-5)		(8-25)
43	Moth (<i>Tinea pellionella</i>)		10	10.2					17.6	47.3		
44	Mollusca											
45	Clam (<i>Mya arenaria</i>)		18	21.5				5	4.5	Trace		51
46	Mussel (<i>Mytilus edulis</i>)		24(17-36)	7.4(Trace-11.4)				9.7(Trace-16)	Trace			58(37-79)
47	Octopus (<i>Octopus vulgaris</i>)		20	50					15	1		14
48	Oyster (<i>Gryphoea angulata</i>)		13.2	7.2					3.2	1.6		75
49	Periwinkle (<i>Littorina littorea</i>)		7	12.6				29	40	0.8		11
50	Sea hare (<i>Aplysia limacina</i>)		13	34(30-37)				(15-167)	8.7(7.4-10)	4.6(Trace-9.2)		(24-45)
51	Slug (<i>Arion empiricorum</i>)		18(11.3-18)	9.8(7.1-9.8)				16.6(3-20)	2.8	3.3(1.4-10.3)		(52-80)
52	Snail (<i>Helix pomatia</i>)		7	22.2				19	16.8	7		35
53	Snail, pond (<i>Limnaea stagnalis</i>)		20	9.0				27.2		4.0		31.6
54	Annelida											
55	Earthworm (<i>Lumbricus terrestris</i>)		(12.2-15)	(20.4-47)				17.5	(10.0-38.1)			10
56	Leech (<i>Hirudo medicinalis</i>)		4.5	78				4.3	3.8			9.1
57	Sea-mouse (<i>Aphrodite aculeata</i>)		35	13.3					11.1	1.1		39
58	Echinodermata											
59	Sea-cucumber (<i>Holothuria tubulosa</i>)		18(18-18.7)	39(39-41)				12(12-12.5)	6(6-6.25)			25(18-25)

/1/ Minus uric acid-N. /2/ Hippuric acid-N. /3/ Trimethylamine oxide-N.

224. PATHWAYS OF BIOSYNTHESIS: PURINES

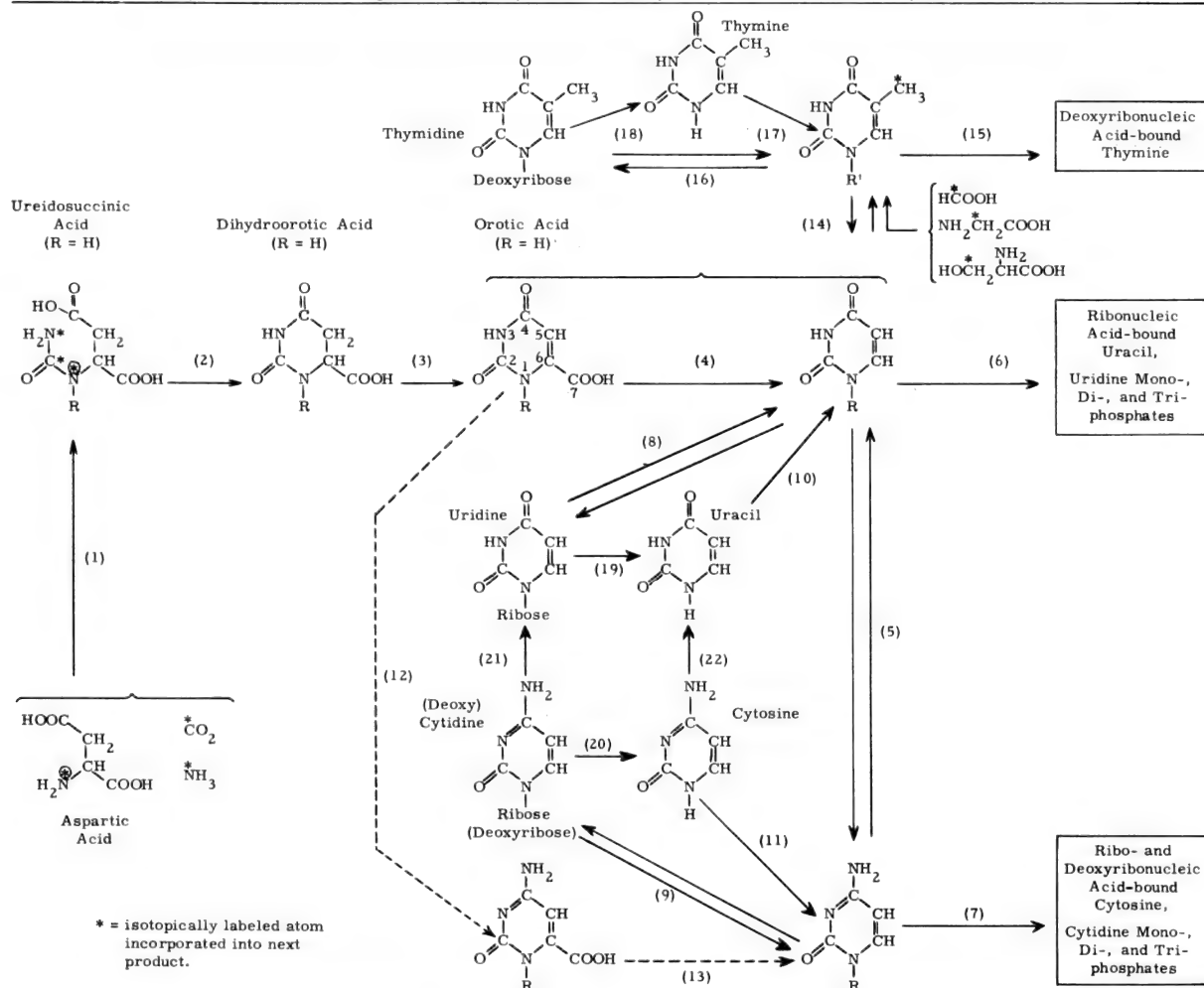
Many of the "reactions" diagrammed probably consist in reality of two or more sequential enzymatic conversions, the resolution of which awaits future developments.



/1/ Simple precursors utilizable in purine biosynthesis in several organisms include ammonium salts, glycine, which contributes purine carbons 4 and 5 and nitrogen 7, and glutamine, the amide nitrogen of which contributes purine nitrogen 9. ATP and PRPP (5'-phosphoribosylpyrophosphate) also are involved in the enzymatic synthesis of the intermediate glycinamide ribotide. /2/ Glycinamide ribotide is formylated in the presence of citrovorum factor or related derivatives to yield α -N-formylglycinamide ribotide. Labeled formate incorporated in this reaction ultimately contributes purine carbon 8. /3/ An aminoimidazole riboside derivative accumulates in cultures of a purineless *Escherichia coli* mutant. In the presence of ATP and glutamine, the amide nitrogen of which contributes purine nitrogen 3, formylglycinamide ribotide is converted enzymatically to aminoimidazole ribotide; the conversion is blocked by azaserine, which therefore enhances accumulation of formylglycinamide ribotide and its precursor. Formylglycinamide ribotide is reported to be an intermediate in aminoimidazole ribotide formation in pigeon liver preparations. /4, 5, 6/ In de novo purine biosynthesis from simple precursors, labeled CO_2 contributes carbon 6. Aspartic acid (the nitrogen of which contributes the nitrogen 1 of purines), ATP, and CO_2 are required in the conversion of aminoimidazole ribotide to aminoimidazole carboxamide ribotide. Accumulation of aminoimidazolecarboxamide and its riboside and ribotide occurs in sulfa-inhibited *E. coli* cultures; accumulation of the carboxamide has been studied also in purineless *E. coli* mutant cultures. Aminoimidazolecarboxamide can be utilized as a purine precursor by several organisms. Enzymatic interconversions of the free base, riboside, and ribotide forms have been reported, including direct conversion of the free base to the ribotide in the presence of PRPP. /7/ The initial purine compound produced in de novo biosynthesis by pigeon liver preparations is inosinic acid. Formate, shown in early work to contribute purine carbon 2, reacts with aminoimidazolecarboxamide ribotide to form inosinic acid, in a conversion involving the citrovorum factor or other activated derivatives of reduced folic acid which may be formed enzymatically in the presence of ATP. Copper is an additional cofactor in the exchange of formate with inosinic acid. /8, 9, 10/ Inosine and hypoxanthine arise secondarily via breakdown of inosinic acid; enzymatic interconversions of these metabolites occur, as well as direct conversion of hypoxanthine to inosinic acid in the presence of ribose-5-phosphate. /11/ The conversion of inosinic acid to other purine compounds (adenine, guanine) may involve as intermediates derivatives such as adenylosuccinic acid. Little is known of the mechanisms of polymerization of nucleotides into nucleic acids; however, a recent report indicates there may be involved the formation of long-chain polynucleotides by linking nucleoside diphosphates together by means of a phosphorylase type of reaction with the liberation of inorganic phosphate. Mono-, di-, and triphosphates of the purines as well as of the pyrimidines have been found to occur free in tissues, and considered as possible precursors in nucleic acid polymerization.

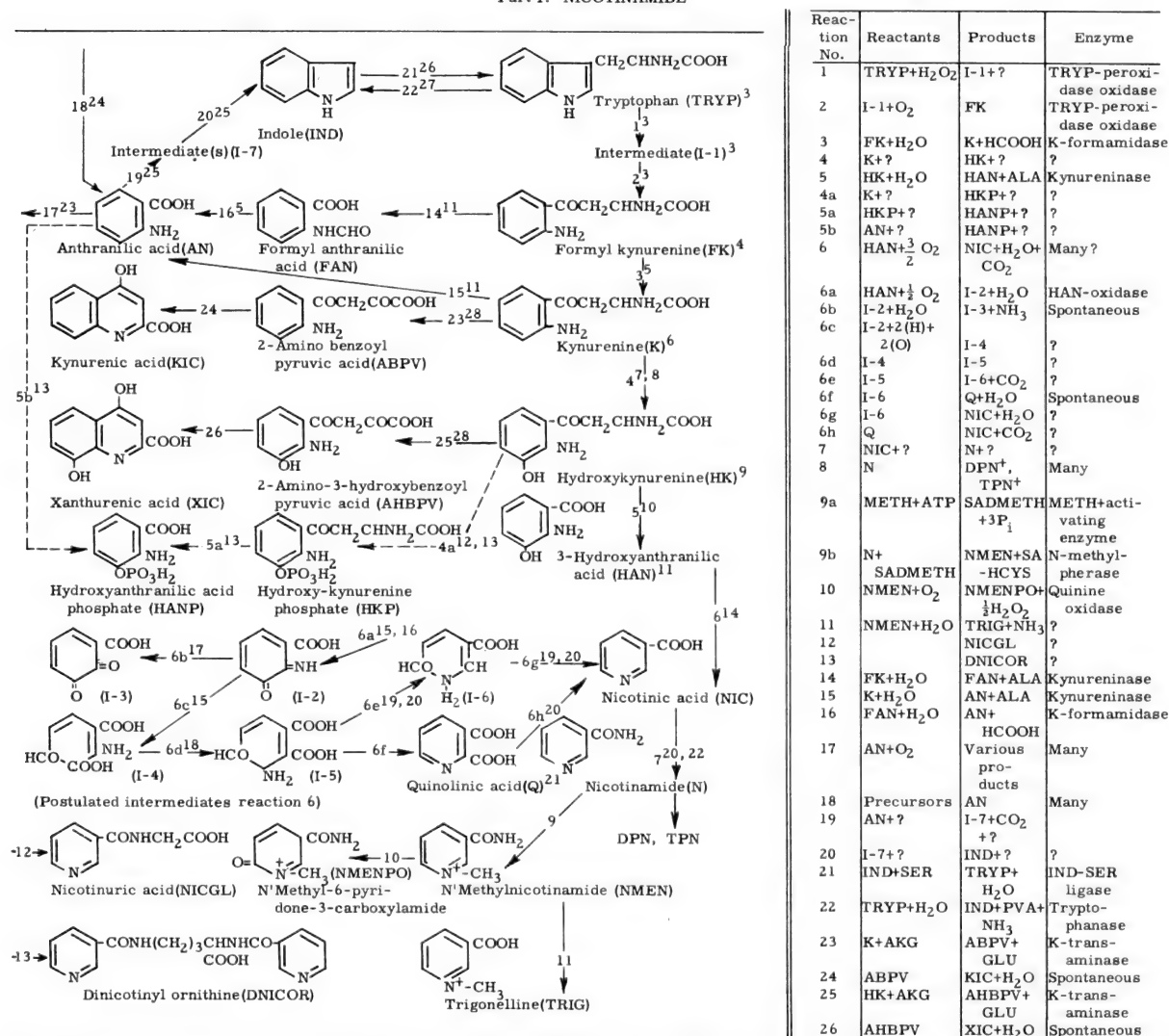
225. PATHWAYS OF BIOSYNTHESIS AND INTERCONVERSION: PYRIMIDINES

Many of the "reactions" diagrammed probably consist in reality of two or more sequential enzymatic conversions.

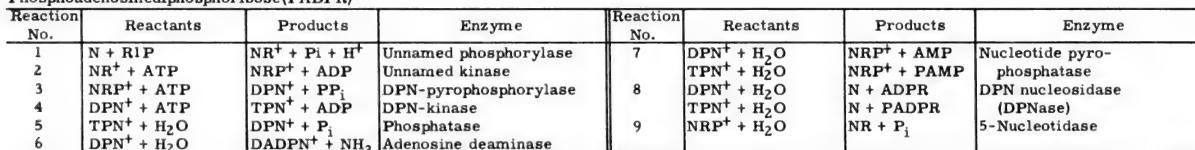
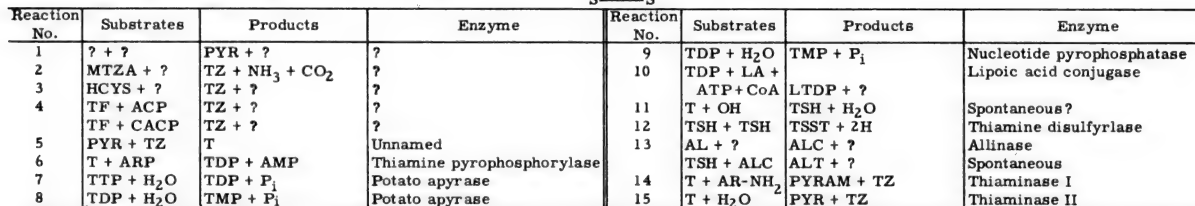


1/ Aspartic acid contributes preferentially nitrogen 1, 2 and less effectively N-3, (ammonium-N contributes preferentially N-3) as well as carbons 4, 5, 6, and 7 to orotic acid in rat liver slices; it contributes the imido-N of ureidosuccinic acid in rat liver mitochondria, and has been shown to be involved in pyrimidine biosynthesis in lactobacilli. Labeled ammonium-N enters nucleic acid cytosine and thymine of pigeons, and enters combined pyrimidines in rats; it is an effective precursor of orotic acid N-1 and N-3 (equally) in rat liver, and of uracil N-1 in rat liver. Labeled ammonium-N contributes the carbamino-N of ureidosuccinic acid in rat liver mitochondria, in a reaction dependent upon ATP, aspartate, and carbamylglutamate. The carbamylation of aspartic acid may be closely analogous to that of ornithine. Labeled bicarbonate, or carboxyl of acetate, enters position 2 of uracil in rats, and of orotic acid in rat liver slices. Labeled CO_2 is fixed into nucleic acid pyrimidines of certain microorganisms. Labeled formate-C does not extensively enter nucleic acid uracil in rats, nor in yeast; the carbons of glycine are not extensively incorporated into the pyrimidine bases of rats. 2, 3/ Ureidosuccinic acid replaces orotic acid for *Lactobacillus bulgaricus* 09, which utilizes no other simple pyrimidine derivatives except as more recently reported, uridine-5'-phosphate and dihydroorotic acid. Ureidosuccinic acid is utilized for orotic acid synthesis in rat liver; it is converted to orotic acid through dihydroorotic acid by certain bacteria. The suggestion has been made that conjugation, such as ribosidation, of an acyclic pyrimidine precursor precedes ring closure and decarboxylation; more recently the free compounds (R=H in diagram) have been suggested as the true intermediates in orotic acid biogenesis. 4/ Orotic acid is utilized by a pyrimidineless *Neurospora* mutant and by *L. bulgaricus* 09 (see above). Orotic acid labeled with N^{15} or C^{14} enters the uridine and cytidine components of liver polynucleotides in rats. Orotic acid-6- C^{14} enters uracil of yeast. 5, 6, 7/ Presumably a conjugated form of uracil is aminated to form a cytosine derivative; such interconversion may take place in the polynucleotide stage. The stage at which pentose is replaced by deoxyribose is not definitely known; labeled C-2 of uracil deoxyriboside incubated with tissue suspensions was incorporated only into DNA thymidine, and no other DNA or RNA component. Little is known of the mechanisms of polymerization of nucleotides into nucleic acids. Mono-, di-, and triphosphates of the pyrimidine ribonucleosides have been found to occur free in tissues, and considered as possible precursors in nucleic acid polymerization; uridine-5'-phosphate is formed from orotic acid by pigeon liver in the presence of 5-phosphoribosylpyrophosphate. 8, 9/ N^{15} -Labeled cytidine, and uridine (with much more isotope dilution), are incorporated by rats into nucleic acids; deoxycytidine is utilized for thymine and cytosine synthesis. 10, 11/ Certain pyrimidineless *Neurospora* mutants utilize uridine or cytidine, or the corresponding free pyrimidines much less effectively. Cytidine and uridine may not be intermediates in uracil utilization in a *Neurospora* strain. Many organisms utilize uracil, cytosine, and their conjugated derivatives interchangeably as growth factors; however, for other microorganisms a specific pyrimidine requirement, e.g. for uracil or uridine, cannot be replaced by other pyrimidines. Although orotic acid (see above) is utilized by rats in nucleic acid formation, neither uracil nor cytosine is so utilized. 12, 13/ It has been suggested that orotic acid after amination may be converted to cytidine and the latter deaminated to uridine. 14, 15/ The stage of pyrimidine synthesis at which the methyl group is introduced to form thymine derivatives is not definitely known. 5-Nitro-uracil competitively inhibits uracil utilization for the formation of a product replaceable by thymine. Uracil is converted to thymine by certain microorganisms. Labeled formate-C, alpha-C of glycine, or beta-C of serine provides the 5-methyl-C of deoxyribonucleic acid thymine in rats. 16, 17/ Some organisms, e.g. *Leuconostoc mesenteroides*, utilize thymine and uracil interchangeably. Thymine is not utilized by rats in nucleic acid formation. Thymidine but not thymine in certain organisms prevents the toxicity of folic acid antagonists of sulfonamides; thymidine is utilized for synthesis of DNA-thymine in rats. In other organisms thymidine and thymine function interchangeably. *Lactobacillus bifidus* utilizes thymidine, thymidylic acid or certain other pyrimidine derivatives for growth. 18, 19, 20/ Nucleosidases for the pyrimidines have been reported. 21, 22/ Enzyme preparations and other biological systems have been reported which deaminate cytosine. An *Escherichia coli* enzyme preparation specifically deaminates cytidine or cytosine deoxyriboside.

226. PATHWAYS OF BIOSYNTHESIS: NICOTINAMIDE, THIAMINE, AND RELATED COMPOUNDS
Part I: NICOTINAMIDE¹



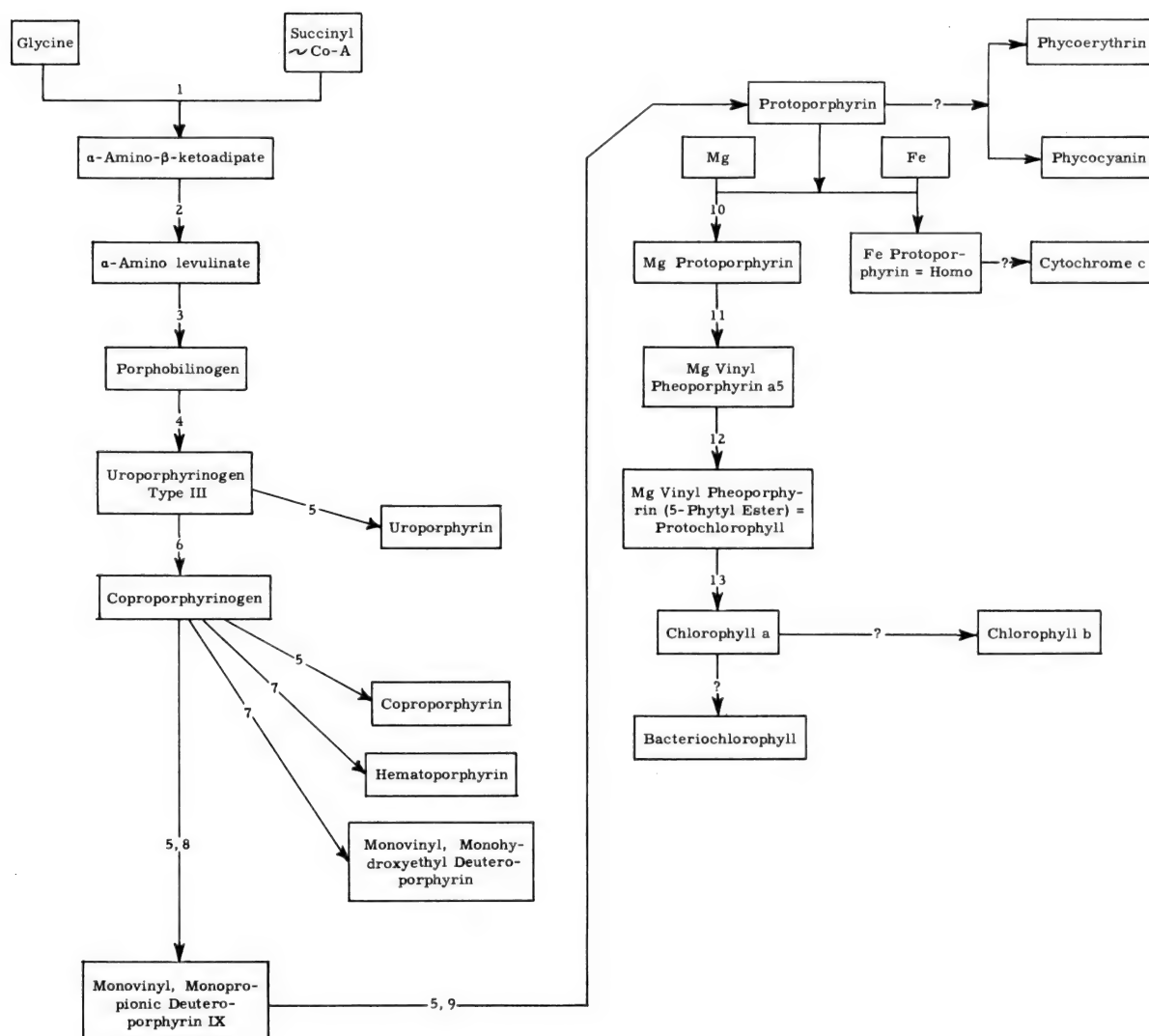
/1/ For definition of most abbreviations see flow diagram; ALA=alanine; METH=methionine; ATP=adenosine triphosphate; AKG=ketoglutaric acid; GLU=glutamic acid; SER=serine; PVA=pyruvic acid; DPN=diphosphopyridine nucleotide; TPN=triphosphopyridine nucleotide. /2/ Dietary TRYP substitutes for N and causes increased formation of NMEN, NIC, Q, and pyridine nucleotides. Tracer experiments have shown that: TRYP-9-C¹⁴→K-8-C¹⁴+KIC-3-C¹⁴; TRYP-3-C¹⁴→NMEN-7-C; TRYP-1-N¹⁵→K-N¹⁵+KIC-N¹⁵+XIC-N¹⁵+NMENPO-N¹⁵; K-N¹⁵→XIC-N¹⁵; TRYP-5, 6, 7, 8-D₄-1-N¹⁵→Q-D₂-1-N¹⁵; IND-1-N¹⁵→NIC-1-N¹⁵; AN-N¹⁵, IND-N¹⁵, or TRYP-1-N¹⁵→TRYP-1-N¹⁵+Q-1-N¹⁵. /3/ Reactions 1 and 2 have not been separated and intermediate not identified. The activity (amount?) of these enzymes is dependent upon the dietary intake of TRYP and is subject to hormonal control. /4/ Suggested compound identified as product of reaction 2. /5/ This enzyme catalyzes reactions 3 and 16 and also acts on other N-formyl compounds. /6/ As N-Acetyl-K, is accumulated by niacinless mutant of *Neurospora*. Dietary K can substitute for N and causes increased excretion of NMEN. /7/ This reaction postulated because of activity of K (Fn 6), HAN (Fn 10), and, subsequently, HK (Fn 9). It has not been shown in cell-free system. /8/ B₂ involved as catalyst in oxidation or oxidative phosphorylation of K. /9/ HK postulated as precursor of HAN. It is a naturally occurring substance and can serve as substitute for NIC in *Neurospora*. /10/ This enzyme catalyzes reactions 5, 14, and 15. It requires pyridoxal phosphate as coenzyme. It is inhibited by amines. /11/ A compound accumulated by niacinless mutant of *Neurospora*, identified as HAN, can substitute for NIC in diet. It is converted to NIC, causes increased excretion of NMEN, and is oxidized to Q by liver preparations. /12/ Reaction and reaction product postulated (see also Fn 13). /13/ Reactions 4a, 4b, and 5b postulated on basis of report that TRYP, K, and AN are oxidized by liver homogenate to product tentatively identified as HANP, whereas HK is split to HAN. However, most authors find that AN is not a source of NIC in mammals. /14/ Reaction well established (see Fn 10) but details still obscure (see reactions 6a-6h). /15/ Reaction 6a or 6c requires O₂ and Fe⁺⁺. It is inhibited by α, α-dipyridyl, p-chloromercuribenzoate, H₂O₂, and HCN. /16/ Intermediate tentatively identified on basis of absorption spectrum, chemical properties, and conversion to I-3. /17/ This reaction, catalyzed by H⁺, gives a product, tentatively identified as I-3, that cannot be converted to Q. /18/ I-4 and I-5 tentatively identified by absorption spectra and chemical properties. /19/ Reaction postulated because of low activity of Q (see Fn 21). /20/ Reaction has not been shown in cell-free system. /21/ Acid-labile substance accumulated in urine identified as Q and is accumulated by niacinless mutant strain of *Neurospora* and mammals. To a limited extent, Q is utilized by *Neurospora* and mammals. May or may not be an intermediate. /22/ Although all mammals appear to utilize either NIC or N interchangeably, the reaction has not been demonstrated in cell-free system. NIC is not necessarily an intermediate. /23/ In some bacteria, AN is oxidized by way of catechol, and cis, cis-muconic acid to β-keto adipic acid. /24/ The ultimate origin of AN from carbohydrate is closely linked with the origin of other aromatic compounds. /25/ The carboxyl group of AN is lost during these reactions. /26/ Enzyme requires pyridoxal phosphate as coenzyme. /27/ Reaction requires pyridoxal phosphate as coenzyme. /28/ Enzyme requires pyridoxal phosphate as coenzyme. Either α-ketoglutaric or pyruvic acid can accept the amino group. With model compounds which cannot undergo ring closure the reaction is reversible. K can be oxidatively deaminated slowly by L-amino acid oxidase to form ABPV which spontaneously dehydrates to KIC. The relative rates of reactions 4, 5, 23, 25 depend upon the dietary intake of B₁, B₂, and B₆.

Part III: THIAMINE AND DERIVATIVES¹

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227. PATHWAYS OF BIOSYNTHESIS: CHLOROPHYLL

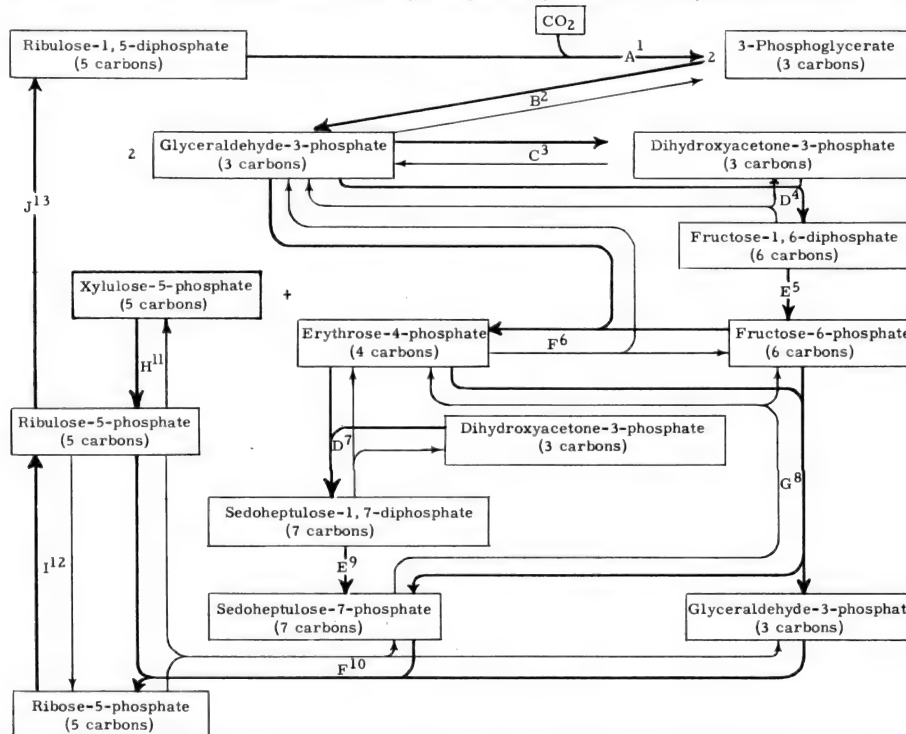
The diagram summarizes present knowledge and hypothesis of the pathway leading to the synthesis of chlorophyll in plants.



/1/ Condensation of glycine with "succinyl~Co-A" produces α-amino-β-ketoadipate. /2/ Decarboxylates to α-amino levulinate. /3/ Two molecules of α-amino levulinate condensed by a dehydrase enzyme, forming the pyrrole amine, porphobilinogen. /4/ Four molecules of porphobilinogen condensed, forming a reduced porphyrin, uroporphyrinogen, isomer III. /5/ It is uncertain how far along the biosynthetic chain tetrapyrrole remains in the reduced form. /6/ Decarboxylation of uroporphyrinogen III to coproporphyrinogen III. /7/ It is uncertain whether these compounds are intermediates or side products. Found in *Chlorella* mutant. /8/ Oxidation of one propionic side chain to vinyl. /9/ Oxidation of one propionic side chain to vinyl, producing protoporphyrin. Found in a *Chlorella* mutant devoid of chlorophyll and carotenoids. /10/ Mg protoporphyrin found in *Chlorella* mutant. /11/ Four or five steps postulated, including reduction of vinyl side chain to ethyl, oxidation of propionic group and cyclization to a cyclopentanone ring, and esterification with methanol. Found in a *Chlorella* mutant. /12/ Esterification of a propionic acid group with phytol, a C-20 alcohol. /13/ Open chain bile pigment chemically bound to protein.

228. PATHWAYS OF PHOTOSYNTHESIS: CARBON DIOXIDE REDUCTION CYCLE

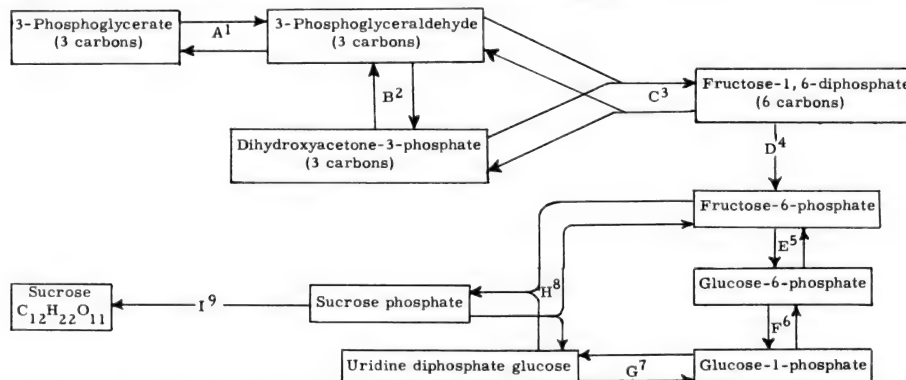
Photosynthetic carbon dioxide-reduction follows the same general pathway in all plants. The first reaction results in formation of two molecules of phosphoglycerate from carbon dioxide and ribulose diphosphate. Phosphoglycerate is then reduced via the reverse of glycolysis reactions to give hexose-phosphates for synthesis of sucrose and polysaccharides. A portion of the intermediates undergoes the following sequence of reactions leading to regeneration of the carbon dioxide acceptor, ribulose diphosphate. Heavy arrows indicate directions of material transfer during steady state photosynthesis. A = Ribulose diphosphate carboxylase (carboxydismutase); B = Triosephosphate dehydrogenase; C = Triosephosphate isomerase; D = Aldolase; E = Phosphatase; F = Transketolase; G = Transaldolase; H = Phosphoketopentose epimerase; I = Phosphoriboisomerase; J = Phosphoribulokinase.



/1/ Ribulose diphosphate adds CO_2 at carbon-2 and splits hydrolytically to give two molecules of 3-phosphoglycerate. /2/ The carboxyl group is reduced to an aldehyde group with the aid of ATP and reduced TPN. /3/ Isomerization involves transfer of 2H from carbon-2 to carbon-1. /4/ Aldol condensation of carbon-1 of glyceraldehyde-3-P with carbon-1 of dihydroxyacetone-3-P. /5/ Removal of phosphate ester group from carbon-1 by hydrolysis. /6/ Glycolyl group (carbon-1,2) of fructose transferred to glyceraldehyde-P to form xylulose-5-P, leaving erythrose-P. /7/ Aldol condensation of carbon-1 of erythrose-4-P with carbon-1 of dihydroxyacetone-3-P obtained from step 3. /8/ Transfer of triose group (carbon-1,2,3) from fructose-6-P to carbon-1 of erythrose-4-P, leaving glyceraldehyde-3-P from carbon-4,5,6 of the fructose-6-P. /9/ Hydrolysis of phosphate ester group on carbon-1 to give inorganic phosphate. /10/ Transfer of glycolyl group (carbon-1,2) of sedoheptulose-7-P to carbon-1 of glyceraldehyde-3-P to give ribulose-5-P, leaving ribose-5-P. /11/ Epimerization of carbon-3 of ketopentose. Xylulose-5-P isomerizes to ribulose-5-P with phosphoketopentose epimerase. /12/ Isomerization of aldose to ketose by transfer of two H atoms. /13/ Phosphorylation of carbon-1 by reaction with ATP.

229. PATHWAYS OF SUCROSE SYNTHESIS: INTERMEDIATES

Sucrose synthesis, common to all green plants, is the first free sugar formed by a series of steps involving phosphorylated intermediates. Photosynthesis supplies reduced pyridine nucleotides and adenosine triphosphate (ATP). Phosphoglycerate, supplied by the photosynthetic carboxylation reaction, is reduced and condensed to form hexose molecules. Energy required to form sucrose from hexose phosphates comes largely from high energy uridine triphosphate (UTP) which becomes uridine diphosphate glucose (UDPG) for condensation with fructose phosphate. A = Triosephosphate dehydrogenase, two types; B = Triosephosphate isomerase; C = Aldolase; D = Phosphatase; E = Phosphoglucosyltransferase; F = Phosphoglucosyltransferase; G = Uridyl transferase; H = Sucrose phosphorylase; I = Sucrose phosphatase.



/1/ DPNH or TPNH are oxidized to supply hydrogen for reduction of carboxyl to aldehyde group. ATP and Mg^{++} are required for this reaction. /2/ Two hydrogen atoms shift from carbon-2 to carbon-1 to form isomeric phosphoketose from 3-phosphoaldotriose. /3/ Aldol condensation of carbon-1 of phosphoketotriose and carbon-1 of 3-phosphoaldotriose. /4/ Phosphate group on carbon-1 hydrolyzed. /5/ Hydrogen atom on carbon-1 shifts to carbon-2 forming the epimer, glucose-6-phosphate. Furanose ring structure changed to pyranose. /6/ Phosphate group on carbon-6 transferred to carbon-1 through the required coenzyme intermediate, glucose-1,6-diphosphate. Mg^{++} required. /7/ UTP reacts with glucose-1-phosphate to form pyrophosphate and UDPG. /8/ Fructose-6-phosphate and UDPG react to give UDP and an unstable sucrose phosphate. /9/ Hydrolysis to give free sucrose and orthophosphate.

230. PHOTOSYNTHESIS: RATES

Photosynthesis under natural conditions is complicated by such factors as light intensity, temperature, CO₂ concentration, and by certain internal conditions of the plant. For a comparison of the rates of photosynthesis, Part I presents maximum rates for natural conditions; Part II, maximum rates for controlled, near-optimum conditions. Part III gives rates as influenced by controlled conditions of temperature, light, and CO₂. Values are apparent rates, i.e., uncorrected for respiration.

Part I: APPARENT MAXIMUM RATES OF PHOTOSYNTHESIS: NATURAL CONDITIONS

Values are mg CO₂/100 sq cm per hr.

Species	CO ₂ Fixation ¹	Species	CO ₂ Fixation ¹
Arctic Zone		Desert Zone	
1 Dock (<i>Rumex acetosella</i>); 10°C	12	20 Atriplex (<i>Atriplex vesicarium</i>)	10
2 Chamaenerium (<i>Chamaenerium latifolium</i>); 0°C	10	21 Date (<i>Phoenix dactylifera</i>)	3.4
3 Cloudberry (<i>Rubus chamaemorus</i>)	8	22 Grape (<i>Vitis vinifera</i>)	16.1
4 Willow (<i>Salix glauca</i>); 10°C	4	23 Heliotrope (<i>Heliotropium argusoides</i>)	27
5 Willow (<i>S. glauca</i>); 20°C	6	24 Limoniastrum (<i>Limoniastrum feei</i>)	1.3
Temperate Zone		25 Oleander (<i>Nerium oleander</i>)	10.3
6 Anemone (<i>Anemone nemorosa</i>)	(6-11)	Tropical Zone	
7 Apple (<i>Pyrus malus</i>)	20(20)	26 Calophyllum (<i>Calophyllum inophyllum</i>)	7.3
8 Corn (<i>Zea mays</i>)	10	27 Cassia (<i>Cassia fistula</i>)	10.9(8.6)
9 Dock (<i>Rumex acetosella</i>)	9	28 Coconut (<i>Cocos nucifera</i>)	0.9
10 Elder (<i>Sambucus nigra</i>)	4.6(1.7)	29 Mango (<i>Mangifera indica</i>)	14.8
11 Fern, polypody (<i>Polypodium virginiana</i>)	(5, 6)	30 Sugarcane (<i>Saccharum officinarum</i>)	5
12 Horse-bean (<i>Vicia faba</i>)	17	Mountain Zone	
13 Mustard (<i>Sinapis alba</i>)	20-26	31 Barley (<i>Hordeum sativum</i>)	≥ 30
14 Oat (<i>Avena sativa</i>)	13	32 Eurotia (<i>Eurotia ceratoides</i>)	≥ 44
15 Pine (<i>Pinus taeda</i>)	14.3(2.5)	33 Gentiana (<i>Gentiana algicola</i>)	≥ 100
16 Potato (<i>Solanum tuberosum</i>)	20	34 Geum (<i>Geum montanum</i>)	48
17 Rhododendron (<i>Rhododendron brachycarpum</i>)	(2, 8)	35 Homogyne (<i>Homogyne alpina</i>)	43(18)
18 Sunflower (<i>Helianthus annuus</i>)	5.5-24	36 Soldanella (<i>Soldanella alpina</i>)	39(19)
19 Tomato (<i>Lycopersicon esculentum</i>)	16.8	37 Veronica (<i>Veronica bellidoides</i>)	65

/1/ Values from determinations made in shade are enclosed in parentheses; all others, in sunlight.

Part II: APPARENT MAXIMUM RATES OF PHOTOSYNTHESIS: NEAR-OPTIMUM CONDITIONS

Species	CO ₂ in Air %	Temperature °C	CO ₂ Fixation, g CO ₂ /hr				Assimilation Time (T _A) ² , sec
			per 100 g wet wt	per 100 g dry wt	per sq dm x 1000	per g chlorophyll (vA) ¹	
1 Basswood (<i>Tilia cordata</i>)	5	25	1.88	5.8	28	6.6	24
Elder (<i>Sambucus nigra</i>)							
2 Green leaves	5	25	1.96	5.3	34	6.6	24
3 Yellow leaves	5	25	0.88	4.7	18	120	1.3
Maple (<i>Acer pseudoplatanus</i>)							
4 Young leaves	5	25	0.98	3.0	16	11.8	13
5 Old leaves	5	25	2.07	5.8	26	5.2	30
6 Poplar (<i>Populus pyramidalis</i>)	5	25	1.90	6.0	40	10.0	16
7 Sunflower (<i>Helianthus annuus</i>)	5	25	2.30	13.4	80	14.0	11
Chlorella (<i>Chlorella pyrenoidosa</i>)							
8 In shade, -- carbonate buffer 9				11.5		4.1	36
9 In light, -- carbonate buffer 9				13.4		2.8	56
10 Sea lettuce (<i>Ulva lactuca</i>)		25			11.8		
11 Sea weed (<i>Gigartina harveyana</i>) ³		16			14		
12 Water net (<i>Hormidium flaccidum</i>)		20				6.8	23

/1/ \sqrt{A} , the assimilation number, i.e., the maximum quantity of CO₂ that can be reduced in unit time by unit quantity of chlorophyll. /2/ The shortest time in which one molecule of chlorophyll can reduce one molecule of CO₂. /3/ In artificial sea water containing 0.016 M bicarbonate/carbonate buffer.

Part III: APPARENT RATES OF PHOTOSYNTHESIS: SPECIFIED CONDITIONS

Species	Temperature ¹ °C	Light ¹ ft-c	CO ₂ in Air ¹	Photosynthesis Rate ²	Unit of Expression per hr
1 Barley (<i>Hordeum vulgare</i>)	24	500	N	9-16	mg CO ₂ /sq dm
2 Bean (<i>Phaseolus vulgaris</i>)	25	1400	N	5.8-16.6	mg CO ₂ /sq dm
3 Dogwood (<i>Cornus florida</i>)	30	2000	N	2(3.1)	mg CO ₂ /sq dm
4 Laurel (<i>Prunus laurocerasus</i>)	29.5	Noon sun	N	23.2	mg CO ₂ /sq dm
5 Lemon (<i>Citrus limonia</i>)		1300	1.5%	3-5	ml O ₂ /sq dm
6 Oak (<i>Quercus rubra</i>)	30	2000	N	5(6)	mg CO ₂ /sq dm
7 Orange (<i>Citrus sinensis</i>)		1300	1.5%	4-6	ml O ₂ /sq dm
8 Pelargonium (<i>Pelargonium zonale</i>)	24	500	N	5.3	mg CO ₂ /sq dm
9 Pine (<i>Pinus taeda</i>)	30	2000	N	2(3.9)	mg CO ₂ /sq dm
10 Potato (<i>Solanum tuberosum</i>)	24	>5000	N	16-20	mg CO ₂ /sq dm
11 Spruce (<i>Picea pungens</i>)	24	2200	N	0.03	mg CO ₂ /100 leaves
12 Sugar cane (<i>Saccharum officinarum</i>)	36	N	N	3-6	mg CO ₂ /sq dm
13 Sunflower (<i>Helianthus annuus</i>)		4460	5%	(80)	mg CO ₂ /sq dm
14 Sphagnum (<i>Sphagnum girgensohnii</i>)		110-260		2.8	mg CO ₂ /g dry wt
15 Chlorella (<i>Chlorella vulgaris viridis</i>)	22.4	26,700 lux	Buffer 9 ³	195	cu mm O ₂ /100 mil cells
16 Chlorella (<i>C. saccharophila</i>)	22.4	26,700 lux	Buffer 9 ³	452	cu mm O ₂ /100 mil cells
17 Kelp (<i>Macrocystis pyrifera</i>)	N	Low	Sea water	17.5	ml O ₂ /sq dm

/1/ Under natural conditions. /2/ Values in parentheses are maximum rates; all others, average rates. /3/ Carbonate buffer 9.

231. PHOTOSYNTHESIS: EFFICIENCY AND CARBON PRODUCTION

Part I: ESTIMATED ANNUAL CARBON PRODUCTION

Region	Area sq km	Carbon Fixed, ton/yr	
		per sq km	total
1 Forest	44 x 10 ⁶	250	11 x 10 ⁹
2 Cultivated land	27 x 10 ⁶	149	4.3 x 10 ⁹
3 Grassland	31 x 10 ⁶	43	1.1 x 10 ⁹
4 Desert	47 x 10 ⁶	7	0.2 x 10 ⁹
5 Total land	149 x 10 ⁶		16.6 x 10 ⁹
6 Ocean	361 x 10 ⁶	340	16.6 x 10 ⁹

Part II: EFFICIENCY OF PHOTOSYNTHESIS

Specification	Value
1 Energy utilized in photosynthesis by one acre of corn plants in synthesis of 8732 kg glucose ¹ .	3.3 x 10 ⁷ Cal
2 Total solar energy available on the acre during growing season.	2.043 x 10 ⁹ Cal
3 Photosynthetic efficiency of corn plants, i.e., per cent of available energy used in photosynthesis.	1.6%
4 Energy equivalent of earth's carbon production.	(13.6±8.1) x 10 ¹⁷ Cal
5 Mean solar radiation.	7.4 x 10 ²⁰ Cal
6 Photosynthetic efficiency of the world.	0.18(±0.12%)

/1/ Total sugar, as glucose, manufactured by one acre of corn plants.

232. PHOTOCHEMICAL ACTIVITIES: PLANTS

Data are concerned with the following: photosynthesis (light dependent reduction of CO_2 with evolution of equimolar O_2), Hill reaction (light dependent reduction of a hydrogen acceptor other than CO_2 with evolution of equivalent O_2), photoreduction (light dependent reduction of CO_2 with oxidation of equivalent exogenous hydrogen donor), photofermentation (light dependent evolution of H_2 and CO_2 from endogenous reserves of exogenous substrate), and photochemical phosphorylation (light dependent esterification of inorganic phosphate). Except where otherwise indicated, light intensity is incident.

Part I: REDUCTION OF CO_2 WITH EVOLUTION OF O_2 : INTACT CELLS

Species	Sample		Temp °C	Radiant Energy		Rate of Reaction
	Units	Total Sample		Type	Intensity ergs/sq cm x sec	
1 <i>Chlorella ellipsoidea</i>	0.192 mg dry wt/ml	20 ml	25	Tungsten lamp	1.15 x 10 ³ 2.41 x 10 ³ 5.30 x 10 ³ 1.04 x 10 ⁴ 2.41 x 10 ⁴ 3.84 x 10 ⁴ Saturation	1.9 x 10 ⁻⁴ $\mu\text{M O}_2$ /mg/sec 3.9 x 10 ⁻⁴ $\mu\text{M O}_2$ /mg/sec 7.6 x 10 ⁻⁴ $\mu\text{M O}_2$ /mg/sec 1.2 x 10 ⁻³ $\mu\text{M O}_2$ /mg/sec 1.5 x 10 ⁻³ $\mu\text{M O}_2$ /mg/sec 1.5 x 10 ⁻³ $\mu\text{M O}_2$ /mg/sec 1.6 x 10 ⁻³ $\mu\text{M O}_2$ /mg/sec
8 <i>C. pyrenoidosa</i>	1.5-2.0 x 10 ⁷ cells/ml 1.2 μl cells/ml	1.0 ml 8.2 ml	28 26	6500 Å Tungsten lamp	616 ergs/sec absorbed 1.51 x 10 ⁴	8.2 x 10 ⁻⁴ $\mu\text{l O}_2$ /sec 9.9 $\mu\text{l O}_2$ /10 min
11 <i>C. vulgaris</i>	1.15 x 10 ⁷ cells/ml	2.4 x 10 ⁸ cells	23-25	Tungsten lamp	8.37 x 10 ² 2.39 x 10 ³ 5.98 x 10 ³ 3.29 x 10 ⁴	0.8 $\mu\text{l O}_2$ /min 1.8 $\mu\text{l O}_2$ /min 3.7-3.8 $\mu\text{l O}_2$ /min 4.7-6.1 $\mu\text{l O}_2$ /min
14 <i>C. vulgaris viridis</i>	10 μl cells/ml	2.0 ml	29.8	Na-vapor lamp	1.45 x 10 ⁴	175 $\mu\text{l CO}_2$ /hr
15 <i>Chlorobium thiosulfatophilum</i>	2.5 mg wet wt/ml	3.0 ml		Tungsten lamp	0.2 0.4 0.6	25 $\mu\text{l CO}_2$ /hr 60 $\mu\text{l CO}_2$ /hr 80 $\mu\text{l CO}_2$ /hr
18 Alfalfa (<i>Medicago sativa</i>)	Whole plant	560 g 560 g 665 g	15.6 15.6 29.7	Sunlight	2.02 x 10 ⁵ 3.37 x 10 ⁵ 5.73 x 10 ⁵	18 g CO_2 /80 min 28 g CO_2 /80 min 39 g CO_2 /80 min
21 Corn (<i>Zea mays</i>)	Whole plant	Entire leaf	18-34 18-34 18-34	Sunlight	3.02 x 10 ⁴ 1.21 x 10 ⁵ 1.51 x 10 ⁵	0.4-2.3 g CO_2 /sq m/hr 1.7 g CO_2 /sq m/hr 0.9-3.5 g CO_2 /sq m/hr

Part II: REACTIONS OTHER THAN AN EXCHANGE OF CO_2 AND O_2 : INTACT CELLS

Species		Sample		Temp °C	Radiant Energy		H ₂ Acceptor or [Donor]	Rate of Reaction
		Units	Total Sample		Type	Intensity erg/sq cm/sec		
Photochemical Reduction, with H ₂ O as H ₂ Donor								
1	Chlorella pyrenoidosa	16 μl cells/ml	3.0 ml	10	Fluorescent lamp	Saturation	p-Quinone	85 μl O ₂ /30 min
2		50 μl cells/ml	2.0 ml	20	Tungsten lamp	Saturation	p-Quinone	165 μl O ₂ /15 min
3		96 mg dry wt/ml	1.0 ml	28	Tungsten lamp	1.36 x 10 ⁴	Benzaldehyde	50 μl O ₂ /20 min
4		96 mg dry wt/ml	1.0 ml	28	Tungsten lamp	1.36 x 10 ⁴	Acetaldehyde	40 μl O ₂ /20 min
Photochemical H ₂ Evolution: Photofermentation								
5	Chlamydomonas moewusii	24 μl cells/ml	4.0 ml	25	Fluorescent lamp	6.0 x 10 ⁴	[Endogenous material]	8.9 μl H ₂ /mg dry wt/hr
6	Chromatium sp	30 μl cells/ml	1.8 ml	30	Tungsten lamp	Optimal	[Endogenous material]	510 μl H ₂ /7.5 hr
7	Rhodospseudomonas gelatinosa	35 μl cells/ml	2.0 ml	30	Tungsten lamp	Optimal	[Endogenous material]	93 μl H ₂ /120 min
8							[Acetic acid]	560 μl H ₂ /120 min
9							[Malic acid]	470 μl H ₂ /120 min
10	Rhodospirillum rubrum	25 μl cells/ml	2.0 ml	30	Tungsten lamp	Optimal	[Malic acid]	170 μl H ₂ /100 min
11		30 μl cells/ml					[Malic acid]	1275 μl H ₂ /20 hr
12		32 μl cells/ml					[Oxalacetic acid]	520 μl H ₂ /240 min
13	Scenedesmus obliquus			25	Tungsten lamp	Optimal	[Endogenous material]	3.7 μl H ₂ /mg dry wt/hr
Photochemical Oxidation of H ₂ : Photoreduction								
14	Chlorobium thiosulfatophilum	2.5 mg wet wt/ml	3.0 ml		Tungsten lamp	0.2	CO ₂	45 μl H ₂ /hr
15						0.4		110 μl H ₂ /hr
16						0.6		185 μl H ₂ /hr
17	Scenedesmus, strain D3	18 μl cells/ml		21	Above 5500 Å	4.5 x 10 ²	CO ₂	43 μl H ₂ /10 min
Photochemical Phosphorylation								
18	Chlorella pyrenoidosa		2.0 μl cells	20	Tungsten lamp	Saturation		3.5 x 10 ⁻⁵ μM P/ μl cells/sec
19	Chromatium, strain D	5 μl cells/ml	50 μl cells	29	Tungsten lamp	1.2-1.3 x 10 ⁴		2.4 μg P/120 min

Part III: PHOTOCHEMICAL REDUCTION: CELL-FREE PREPARATIONS

Data are photochemical reductions, with water as hydrogen donor (Hill reaction).

Algae, Liverworts, Horsetails				Spermatophytes: Broadleaf (concluded)				
1	Chlorella pyrenoidosa	0.24	400	13	Beet (Beta vulgaris)	0.64	1490	
2	C. vulgaris	0.38	210	14	Cabbage (Brassica oleracea)	0.70	590	
3	Conocephalum conicum	0.19	200	15	Chickweed (Stellaria media)	0.72	540	
4	Equisetum arvense	0.83	240	16	Duckweed (Lemna minor)	0.56	430	
5	E. scirpoides	1.60	700	17	Duckweed (Wolffia punctata)	0.24	680	
Spermatophytes: Grasses				18	Lettuce (Lactuca sativa)	0.38	1010	
6	Barley (Hordeum vulgare)	1.50	540	19	Melon (Cucumis melo)	0.61	620	
7	Corn (Zea mays)	1.16	270	20	New Zealand spinach (Tetragonia expansa)	0.61	950	
8	Millet (Panicum miliaceum)	0.71	2300	21	Parsley (Petroselinum hortense)	0.68	130	
9	Oat (Avena sativa)	1.40	660	22	Spinach (Spinacea oleracea)	0.56	1940	
10	Rye (Secale cereale)	1.60	890	23	Sweetpea (Lathyrus odoratus)	1.54	170	
11	Wheat (Triticum aestivum)	1.14	760	24	Tobacco (Nicotiana glauca grandiflora)	1.01	100	
Spermatophytes: Broadleaf				25	Tobacco (N. tabacum)	0.80	190	
12	Bean (Phaseolus vulgaris)	0.48	370	26	Tomato (Lycopersicon esculentum)	1.60	300	
Species		Sample		Total Sample	Radiant Energy		H ₂ Acceptor	Rate of Reaction μl O ₂ /min
		Type	Unit		Type	Intensity ³		
27	Spinach (Spinacea oleracea)	Granula	0.75-1.0 mg chlorophyll/ml	2 ml	Tungsten lamp	2.85 x 10 ⁴	p-Quinone	6.0
28							1, 2-Naphthoquinone-4-sulfonate	5.0
29							1, 4-Naphthoquinone-2-sulfonate	4.0
30							9, 10-Anthroquinone-4-sulfonate	1.5

/1/ mg chlorophyll. /2/ Data, expressed as $\mu\text{l O}_2$ /mg chlorophyll/hr, are applicable to the following specifications: preparation, chloroplasts; hydrogen acceptor, $\text{K}_3\text{Fe}(\text{CN})_6 + \text{K}_2\text{C}_2\text{O}_4$; radiant energy source, >5350 Å; intensity, 4.8 x 10⁴ erg/sq cm/sec. /3/ erg/sq cm/sec.

233. NITROGEN FIXATION

Certain organisms fix atmospheric nitrogen in organic combination. Part I presents estimated amounts of nitrogen fixed per acre by symbiotic (rhizobia-legumes) and saprophytic bacteria. The amount of nitrogen fixed from the air by the symbiotic relation of rhizobia and legumes is influenced by effectiveness of the rhizobia, host species, soil and climatic conditions, and individual handling of the crop. Part II reveals strain and host specificity. Part III shows characteristics of various nitrogen-fixing organisms.

Part I: NITROGEN FIXING: BACTERIA, LEGUMES	
Organism	N Fixed Kg/acre
Rhizobium spp - Legumes	
Inoculated with <i>Rhizobium meliloti</i>	
1 Alfalfa (<i>Medicago sativa</i>)	88(25-170)
2 Burclover (<i>M. denticulata</i>)	35(23-49)
3 Fenugreek (<i>Trigonella foenum-graecum</i>)	37
4 Sourclover (<i>Melilotus indica</i>)	45
5 Sweetclover (<i>M. alba</i>)	54(30-75)
Inoculated with <i>R. trifolii</i>	
6 Clover (<i>Trifolium incarnatum</i>)	42(32-53)
7 Clover (<i>T. pratense</i>)	52(19-78)
8 Clover (<i>T. repens</i>)	47(35-65)
9 Clover (<i>T. repens giganteum</i>)	81(72-91)
Inoculated with <i>R. leguminosarum</i>	
10 Lentil (<i>Lens culinaris & esculenta</i>)	47
11 Pea (<i>Pisum arvense</i>)	23(20-28)
12 Pea (<i>P. sativum</i>)	33(13-60)
13 Vetch (<i>Vicia spp</i>)	36(20-63)
Inoculated with <i>R. phaseoli</i>	
14 Bean (<i>Phaseolus vulgaris</i>)	18
Inoculated with <i>R. japonicum</i>	
15 Soybean (<i>Glycine soja</i>)	26(7-48)
Inoculated with <i>R. lupini</i>	
16 Lupine (<i>Lupinus angustifolius</i>)	68
Inoculated with <i>Rhizobium spp</i>	
17 Cowpea (<i>Vigna sinensis</i>)	41(26-53)
18 Garbanzo (<i>Cicer arietinum</i>)	30
19 Kudzu (<i>Pueraria thunbergiana</i>)	49(40-57)
20 Lespedeza (<i>Lespedeza striata & stipulacea</i>)	39(15-94)
21 Peanut (<i>Arachis hypogaea</i>)	19
22 Velvetbean (<i>Stizolobium deeringianum</i>)	30
23 Pastures with legumes	48(5-91)
Saprophytic Bacteria	
24 Azotobacter	12-17
25 Clostridium	1-2

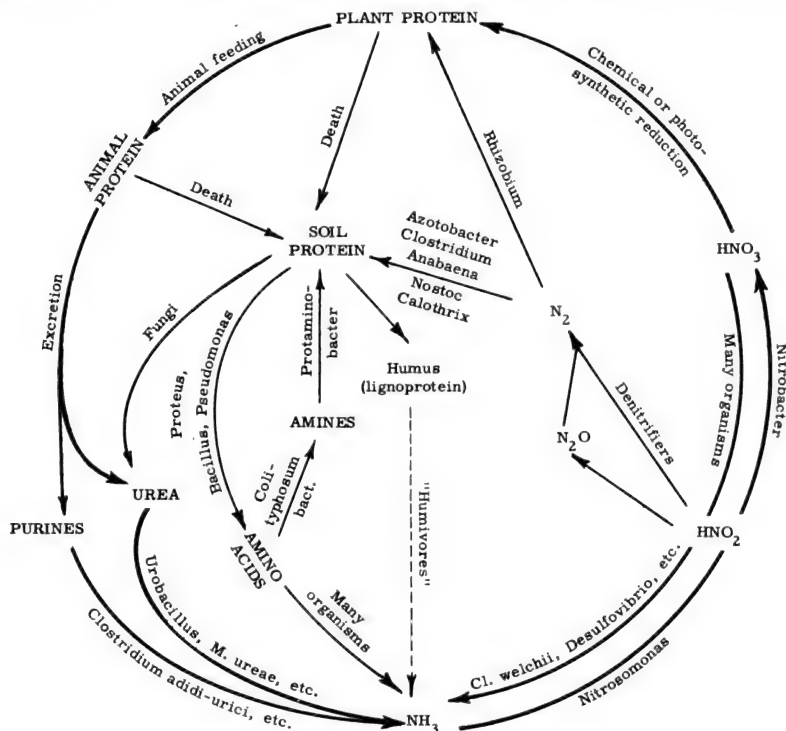
Part II: NITROGEN FIXING: STRAIN-HOST RELATION				
Organism	N Fixed with Rhizobia Strains ¹			
	RT 1	RT 16	RT 8	RT 13
	mg/8 plants			
1 Clover (<i>Trifolium pratense</i>)	54	34	3	2
2 Clover (<i>T. repens</i>)	60	46	10	7
3 Clover (<i>T. subterranean</i>)	8	7	138	154
/1/ Strains of Rhizobium trifolii. RT 1 isolated from Trifolium pratense; RT 16, from T. repens; RT 8 and 13, from T. subterranean.				

Part III: NITROGEN-FIXING: ORGANISMS			
Organism	Essential Symbiotic Relationship	O ₂ Relation	Type ¹
<i>Rhizobium</i> ²			
1 <i>R. meliloti</i> ³	Medicago, Melilotus	Aerobic	Het.
2 <i>R. trifolii</i>	Trifolium	Aerobic	Het.
3 <i>R. leguminosarum</i>	Pisum	Aerobic	Het.
4 <i>R. phaseoli</i>	Phaseolus	Aerobic	Het.
5 <i>R. japonicum</i>	Glycine	Aerobic	Het.
6 <i>R. lupini</i>	Lupinus	Aerobic	Het.
7 Various spp	Vigna, Lespedeza	Aerobic	Het.
8 Azotobacter ³	None	Aerobic	Het.
9 Clostridium ⁴	None	Anaerobic	Het.
10 Desulfovibrio	None	Anaerobic	Het.
11 Rhodospseudomonas and Rhodospirillum	None	Anaerobic ⁵	Het.
12 Chromatium	None	Anaerobic	Aut.
13 Chlorobacterium	None	Anaerobic	Het.
14 Rhodomicrobium	None	Anaerobic	Het.
15 Nostoc & Calothrix ³	None	Aerobic	Aut.

^{1/1} Het. = heterotrophic; Aut. = autotrophic. ^{2/2} Nitrogen fixation inhibited by 2, 4-D and by seed treatments containing Cu; slightly inhibited by DDT. ^{3/3} Inhibited by NH₄ and NO₃; stimulated by Mo. ^{4/4} Inhibited by NH₄, stimulated by Mo. ^{5/5} Fixation is best under anaerobic conditions in light only; traces under aerobic in dark. Organism is facultative.

234. THE NITROGEN CYCLE IN NATURE

Adapted from Thimann, K. V., "The Life of Bacteria," Macmillan Co., 1955.



235. PRODUCTS OF CARBOHYDRATE METABOLISM: MOLDS

Products listed include only compounds (both diffusible and confined to the mycelium) produced on media containing glucose or sucrose, by the more common fungi (*Mucor*, *Rhizopus*, *Aspergillus*, *Penicillium*, *Alternaria*, *Helminthosporium*). The well-known antibiotics have been omitted. The organisms listed do not constitute the only species producing the compound but, for the most part, the more common ones or those used industrially. Most figures on yield are approximate, frequently based on weights of crude product or pure material after losses in purification. Yields may differ widely among strains of the same species.

Metabolic Product	Produced By	Yield
	Organic Acids, Aldehydes, Alcohols and Related Compounds	
1 Acetaldehyde	Various <i>Penicillia</i> , <i>Aspergilli</i> , <i>A. niger</i> , <i>Mucor</i> species, and many other genera. By fixation with intercepting agents.	Up to 60% of theory when grown on sucrose with <i>Aspergillus niger</i> .
2 Acetic acid	<i>Fomes annosus</i> , <i>Marasmius chordalis</i> , <i>Merulius confluens</i> , <i>M. lachrymans</i> , <i>M. niveus</i> , <i>M. tremellosus</i> .	0.6% - 0.9% of glucose used for <i>Merulius lachrymans</i> and <i>Marasmius chordalis</i> .
3 Ascorbic acid	<i>Aspergillus niger</i> .	0.2% of the glucose consumed.
4 Clavacin ¹ (claviformin or patulin)	<i>Aspergillus clavatus</i> , <i>Penicillium expansum</i> , <i>P. claviforme</i> , <i>P. patulum</i> .	2.2% of glucose added.
5 Citric acid	<i>Citromyces</i> , <i>Penicillium luteum</i> , <i>P. citrinum</i> , <i>P. spinulosum</i> , <i>Aspergillus niger</i> , <i>A. clavatus</i> , <i>A. itaconicus</i> , <i>A. wentii</i> , <i>Mucor pyriformis</i> , many other species. Commercial production on beet and cane molasses. Submerged production possible but not yet commercially successful.	As high as 90% of theory.
6 i-Erythritol	<i>Penicillium brevi-compactum</i> , <i>P. cyclopium</i> .	0.7% of the weight of the organism.
7 Ethyl acetate	<i>Penicillium digitatum</i> .	0.6% of the sugar consumed.
8 Ethyl alcohol	<i>Fusarium</i> species, <i>Mucor</i> species, <i>Merulius</i> species, various <i>Penicillia</i> and <i>Aspergilli</i> , <i>Fomes annosus</i> . Production much slower than by yeast.	Stoichiometric yield with <i>Fusaria</i> , <i>Merulius</i> species, <i>Fomes annosus</i> grown on hexoses and pentoses.
9 Formic acid	<i>Aspergillus oryzae</i> .	50% of theoretical yield after 30 days.
10 Fumaric acid	Various species of <i>Rhizopus</i> ; <i>Aspergillus fumigatus</i> , <i>Penicillium griseofulvum</i> , <i>Caldariomyces fumago</i> . Most species other than <i>Mucorales</i> give small amounts.	
11 Fumigacin ¹	<i>Aspergillus fumigatus</i> , <i>A. fumigatus</i> mut. <i>helvola</i> .	0.02 - 0.15% of the glucose added.
12 Gentsyl alcohol	<i>Penicillium patulum</i> .	2.3% of the glucose added.
13 Gladiolic acid	<i>Penicillium gladioli</i> .	94 mg/liter of Raulin-Thom medium.
14 Gluconic acid	<i>Penicillium chrysogenum</i> , <i>P. luteum</i> , <i>P. purpurogenum</i> , <i>Aspergillus</i> species, <i>Fusarium lini</i> bolley.	Practically quantitative conversion in 24 hours.
15 Glucose	<i>Aspergillus niger</i> . From tartaric acid, lactic acid, mannitol and quinic acid.	
16 Glutaric acid	<i>Aspergillus niger</i> strains.	
17 Glycerol	<i>Mucor racemosus</i> , <i>Aspergillus wentii</i> , white <i>Aspergilli</i> , <i>Clasterosporium</i> and <i>Helminthosporium</i> .	Usually small amounts; some species, 3% of the glucose consumed.
18 Glycolic acid	<i>Aspergillus niger</i> (from acetate).	Traces.
19 Glycuronic acid	<i>Ustilina vulgaris</i> .	
20 Glyoxylic acid	<i>Aspergillus niger</i> (from acetate), <i>Merulius lachrymans</i> .	Traces.
21 Itaconic acid	<i>Aspergillus terreus</i> , <i>A. itaconicus</i> .	As high as 50% of theoretical yield.
22 Itatartaric acid	<i>Aspergillus terreus</i> mutant.	1.5% of glucose added.
23 Kojic acid	<i>Aspergillus flavus</i> - <i>oryzae</i> - <i>tamaris</i> group, <i>A. wentii</i> .	45-55% in 12 days. 63-66% reported.
24 D-Lactic acid	Practically confined to <i>Mucorales</i> . Various <i>Rhizopus</i> species, i.e., <i>R. stolonifer</i> , <i>oryzae</i> , <i>japonicus</i> , <i>tritici</i> , <i>arrhizus</i> . Fumaric acid produced by altering conditions.	Up to 62% with <i>R. oryzae</i> , 39-40% with <i>R. japonicus</i> .
25 Malic acid	White species of <i>Aspergillus</i> , <i>A. flavus</i> , <i>Clasterosporium</i> sp. Accompanied by succinic and fumaric acids.	Fair yields by submerged growths when growing at low temperatures.
26 Malonic acid	<i>Penicillium funiculosum</i> .	
27 Mannitol	White species of <i>Aspergillus</i> , many <i>Aspergilli</i> , <i>Byssoschlamys fulva</i> , <i>Penicillium griseofulvum</i> . Not produced from fructose.	45-50% of theory.
28 Mellein ² (ochracin)	<i>Aspergillus melleus</i> , <i>A. ochraceus</i> .	300 mg/l of medium on sucrose.
29 Methyl glyoxal	<i>Aspergillus niger</i> . On hexosediphosphate.	16% of the substrate consumed.
30 Methyl salicylic acid	<i>Penicillium griseofulvum</i> , <i>P. flexuosum</i> .	2.4% of the glucose consumed.
31 Oxalic acid	<i>Citromyces</i> , <i>Aspergillus</i> , <i>Penicillium</i> and many other genera. Can be produced more economically by other methods.	50% of the sugar consumed.
32 Penicillic acid ¹	<i>Penicillium cyclopium</i> , <i>P. puberulum</i> , <i>Aspergilli</i> .	4.2% of the glucose consumed.
33 Propionic acid	<i>Botrytis cinerea</i> . On lactate.	
34 Pyruvic acid	<i>Aspergillus niger</i> (in presence of sodium sulfite as interceptor), <i>Fusaria</i> .	8.2% of the glucose consumed.
35 Saccharic acid	<i>Aspergillus niger</i> .	
36 Spiculosporic acid ³	<i>Penicillium spiculispurum</i> , <i>P. crateriforme</i> , <i>P. minio-luteum</i> .	Approx. 2% of the sugar utilized.
37 Succinic acid	<i>Mucor stolonifer</i> , <i>Aspergillus terreus</i> , <i>Ustilina vulgaris</i> , <i>Penicillium aurantio-virens</i> , <i>P. spiculospurum</i> , <i>Fusarium oxysporum</i> , <i>F. heterosporum</i> , <i>F. lini</i> bolley, <i>Fomes annosus</i> , <i>Merulius confluens</i> , <i>M. niveus</i> , <i>M. tremellosus</i> .	Yields very small, except for <i>Fusarium</i> species.
38 Ustic acid	<i>Aspergillus ustus</i> .	0.6% of glucose added.
	Pigments	
39 Alboleersin (colorless) ⁴	<i>Helminthosporium leersii</i> .	0.4% of mycelial weight.
40 Aurofusarin	<i>Fusarium culmorum</i> , <i>F. graminearum</i> .	Up to 4.4% of mycelial weight.
41 Auroglaucin	<i>Aspergillus glaucus</i> sp.	More than 13% of the dry growth.
42 β-Carotene	<i>Neurospora</i> , <i>Mucor hiemalis</i> , <i>Phycomyces blakesleanus</i> .	Traces.
43 γ-Carotene	<i>Allomyces</i> species.	Traces.
44 Carviolacin	<i>Penicillium roseopurpureum</i> (<i>P. carminoviolaceum</i>).	3.0% of mycelium (crude pigment).
45 Carviolin	<i>Penicillium roseopurpureum</i> (<i>P. carminoviolaceum</i>).	3.0% of mycelium (crude pigment).
46 Catenarin ⁵ (1-hydroxyemodin)	<i>Helminthosporium catenarium</i> , <i>H. gramineum</i> , <i>H. velutinum</i> , <i>H. tritici-vulgaris</i> .	As much as 10% - 40% of the mycelial weight in <i>Helminthosporium gramineum</i> , 20% in <i>H. catenarium</i> .
47 Chrysogenin	<i>Penicillium chrysogenum</i> .	
48 Chrysophanic acid (chrysophanol)	<i>Penicillium islandicum</i> .	0.1% of dried mycelium.
49 Citrinin ¹	<i>Penicillium citrinum</i> , <i>Aspergillus terreus</i> .	3.4% of the sugar consumed.
50 Citromycin	<i>Citromyces glabrum</i> (<i>Penicillium frequentans</i> group).	As much as 20% sugar metabolized.
51 Cynodontin ⁵	<i>Helminthosporium cynodontis</i> , <i>H. euchlaenae</i> , <i>H. avenae</i> .	Up to 4.2% of mycelium.
52 Emodic acid	<i>Penicillium cyclopium</i> .	0.1% (as acetyl derivative) of glucose supplied.

/1/ Possesses antibiotic properties but is not in clinical use. /2/ Converted to methyl salicylic acid on KOH fusion. /3/ Related to minioluteic acid. /4/ Related to luteoleersin. /5/ Compare Items 46, 51, 59, and 78. Different species of *Helminthosporium* have different proportions of these pigments.

235. PRODUCTS OF CARBOHYDRATE METABOLISM: MOLDS (Concluded)

Metabolic Product	Produced By	Yield
Pigments (concluded)		
53 Ergoflavin	<i>Sclerotium clavus</i> .	
54 Erythroglaucon	<i>Aspergillus glaucus</i> group, 15 species.	0.25% of the mycelium (pure).
55 Flavoglaucan	<i>Aspergillus glaucus</i> .	More than 25% of the dry growth weight.
56 Fulvic acid	<i>Penicillium griseofulvum</i> , <i>P. flexuosum</i> , <i>P. brefeldianum</i> .	15-20% of the mycelium, 2.7% of the glucose consumed.
57 Fumigatin	<i>Aspergillus fumigatus</i> .	0.35% of the glucose consumed (crude material).
58 Fusarubin	<i>Fusarium solani</i>	On sucrose 25 mg/liter of medium.
59 Helminthosporin ⁵	<i>Helminthosporium gramineum</i> , <i>H. catenarium</i> , <i>H. tritici-vulgaris</i> , <i>H. cynodontis</i> .	As much as 22% - 40% of the mycelial weight in <i>H. gramineum</i> .
60 ω -Hydroxyemodin	<i>Penicillium cyclopium</i> , <i>P. citreo-roseum</i> , <i>P. cyaneo-fulvum</i> .	0.1% of glucose (tetraacetyl derivative) supplied.
61 Islandicin	<i>Penicillium islandicum</i> .	3% of the mycelium.
62 Javanicin	<i>Fusarium javanicum</i> .	0.05% of the glucose added (pure).
63 Luteoleersin ⁶	<i>Helminthosporium leersii</i> .	1.8% of the mycelium.
64 Lycopersin	<i>Fusarium lycopersici</i> .	
65 Monascoflavin	<i>Monascus purpureus</i> .	
66 Monascorubrin	<i>Monascus purpureus</i> .	
67 Nalgiovensin	<i>Penicillium nalgiovensense</i> .	1% of dry mycelium.
68 Oosporein	<i>Oospora colorans</i> .	9.5% of the substrate added.
69 Oxy-javanicin	<i>Fusarium javanicum</i> .	0.02% of the glucose added (pure).
70 Penetrinic acid	<i>Penicillium notatum</i> .	
71 Penicilliopepsin	<i>Penicilliopepsis clavariaeformis</i> .	7.5% of the mycelium.
72 Phoenicin	<i>Penicillium phoeniceum</i> , <i>P. rubrum</i> (also <i>Bacillus pyocyaneus</i>).	1.2% (pure) of mycelium.
73 Physcion (Emodin monomethyl ether)	<i>Aspergillus glaucus</i> species.	0.65% of the mycelium (pure).
74 Ravenelin	<i>Helminthosporium ravenelii</i> , <i>H. turcicum</i> .	10% of the mycelium.
75 Rugulosin	<i>Penicillium rugulosum</i> .	
76 Solanione	<i>Fusarium solani</i> D ₂ purple.	
77 Spinulosin (6-hydroxyfumigatin)	<i>Penicillium spinulosum</i> , <i>P. cinerascens</i> , <i>Aspergillus fumigatus</i> .	0.11% of the glucose consumed (<i>A. fumigatus</i>).
78 Tritisporin ⁵	<i>Helminthosporium tritici-vulgaris</i> , <i>Helminthosporium</i> species.	1.4% of the mycelium.
Chlorine-containing Compounds		
79 Caldariomycin	<i>Caldariomyces fumago</i> .	0.4% of the glucose consumed.
80 Erdin ⁷	<i>Aspergillus terreus</i> .	0.6% of the sugar consumed.
81 Geodin ⁷	<i>Aspergillus terreus</i> .	0.5% of the sugar consumed.
82 Griseofulvin ¹	<i>Penicillium griseofulvum</i> , <i>P. janczewskii</i> .	2% of the mycelium.
83 Nalgiolaxin ⁸	<i>Penicillium nalgiovensense</i> .	0.18% of dry mycelium.
84 Sclerotiorine	<i>Penicillium sclerotiorum</i> .	2% of the mycelium.
Polysaccharides		
85 Capreolinos ⁹	<i>Penicillium capreolinum</i> .	
86 Glycogen ¹⁰ (red-brown I ₂ color)	White species of <i>Aspergillus</i> , <i>Penicillium digitatum</i> .	
87 Gums	<i>Oidium</i> sp., <i>Penicillium lactis</i> , <i>P. guttulosum</i> , <i>Monilia candida</i> , <i>Mucor racemosus</i> .	38% on 10% mannose.
88 Levan ¹¹	<i>Aspergillus sydowii</i> .	(From sucrose only).
89 Luteic acid (Luteose) ¹²	<i>Penicillium luteum</i> .	10-12%.
90 Mold starch ¹⁰ (blue I ₂ color)	<i>Penicillium</i> species.	
91 Mycodextran ¹⁰ (no I ₂ color)	<i>Penicillium expansum</i> , <i>Aspergillus niger</i> .	2% of the growth.
92 Mycogalactan ¹³	<i>Aspergillus niger</i> (produced along with Mycodextran).	
93 Polygalactose ¹³ (galactocarolose)	<i>Penicillium charlesii</i> .	Approx. 4% of the sugar consumed (crude).
94 Polymannose ¹⁴	<i>Penicillium charlesii</i> .	Approx. 4% sugar consumed (crude).
95 Rugulose ¹³	<i>Penicillium rugulosum</i> .	
96 Sclerotiose ¹⁰	<i>Penicillium sclerotiorum</i> .	10% of the mycelial weight.
97 Varianose ¹⁵	<i>Penicillium varians</i> .	Approx. 1% of the glucose consumed (crude material).
Sterols and Lipids		
98 Ergosterol	<i>Aspergillus niger</i> , <i>A. oryzae</i> , <i>Fusarium lycopersici</i> , <i>F. lini</i> , <i>bolleyi</i> , <i>Helminthosporium avenae</i> , <i>H. ravenelii</i> , <i>H. velutinum</i> , <i>Lentinus lepideus</i> , <i>Penicillium expansum</i> , <i>P. puberulum</i> .	0.13% - 1.7% of mycelium.
99 Ergosteryl palmitate	<i>Penicillium brevi-compactum</i> , <i>P. italicum</i> .	0.5% of the growth, 0.6% of the glucose consumed.
100 Fat	All organisms.	Various.
101 Lecithin	<i>Aspergillus oryzae</i> (spores).	
102 Lecithin and cephalin	<i>Aspergillus sydowii</i> .	0.43-0.73%.
103 Phosphatides	<i>Aspergillus oryzae</i> , <i>A. sydowii</i> , <i>A. citromyces</i> .	
104 Sterols	<i>Aspergillus fischeri</i> , <i>Penicillium puberulum</i> , <i>Paecilomyces varioti</i> , <i>Fusaria</i> .	0.13%-1.0% of the dry mycelium.
Nitrogen-containing Compounds		
105 Adenine	<i>Aspergillus niger</i> .	0.05%.
106 Aspergillic acid	<i>Aspergillus flavus</i> .	1% of the carbohydrate added.
107 Betaine	<i>Aspergillus oryzae</i> (spores).	
108 Choline sulfate	<i>Aspergillus sydowii</i> (from hydrolysis of mycelium).	
109 Hypoxanthine	<i>Aspergillus oryzae</i> , <i>Rhizopus japonicus</i> .	
110 Lycomarasin (asparagylglycylhydroxyalanine)	<i>Fusarium lycopersici</i> .	110 mg/l of medium on glucose.
111 Stachydrine (n-methyl-proline-methyl betaine)	<i>Aspergillus oryzae</i> , <i>Rhizopus japonicus</i> .	
112 Thiamine	<i>Fusarium lini</i> bolley.	20 gammas/gram of mycelium.
113 Urea	<i>Penicillium johannoli</i> , <i>Aspergillus niger</i> , <i>Rhizopus nigricans</i> .	
114 Uric acid	<i>Aspergillus oryzae</i> (spores).	

/1/ Possesses antibiotic properties but is not in clinical use. /5/ Compare Items 46, 51, 59, and 78. Different species of *Helminthosporium* have different proportions of these pigments. /6/ Related to alboleersin. /7/ Geodin and erdin are closely related compounds. /8/ Mono-chloronal-giovensin. /9/ Hydrolysis yields mannose, glucose, galactose and mannonic acid. /10/ Hydrolysis yields glucose. /11/ Hydrolysis yields fructose. /12/ Hydrolysis yields β -glucose-malonic acid (2:1), demalonylated luteic acid. /13/ Hydrolysis yields galactose. /14/ Hydrolysis yields mannose. /15/ Hydrolysis yields D-glucose, D-galactose and D-idose or L-altrose.

236. METABOLIC RATES: SOIL ORGANISMS

In columns B D F I K the following symbols are used: μ = a millionth of a millionth (10^{-12}); μ = a millionth (10^{-6}); m = a thousandth (10^{-3}); M = million (10^6). Values in columns I J K are included only to indicate the order of magnitude of the metabolic activity of representative groups of organisms.

Indicate the order of magnitude of the metabolic activity of representative groups of organisms.				Metabolic Rate				Respiratory Quotient ³	Typical Estimates, Natural Soils		
Organism	Weight mg	Temperature ¹ °C	Calories ²		Oxygen Consumption		Number Per sq m		Mass g/sq m	Metabolism Cal/hr/sq m	
			Cal/ind/hr ⁴	Cal/kg/hr	ml/ind/hr ⁵	L/kg/hr					
(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	(J)	(K)	
1 Bacteria								200-1200 MM	200-1200	330 m	
2 Acetobacter						250 ⁶					
3 Azotobacter						750 ⁶					
4 Escherichia coli						25-75 ⁶					
5 Sarcina lutea	1 mμ	20.5	33 m μμ	33	7 μμ	7	0.71				
6 Fungi									40-400		
7 Mycoderma sp	100 mμ	20.0	0.024 mμ	238	4.9 mμ	49	(0.82)				
8 Saccharomyces sp	180 mμ	20.0	8.7 μμ	48.1	1.8 mμ	10	(0.82)				
9 Protozoa								100-500 M	38	21-32 m	
10 Chaos chaos (ameba)	0.05	22.5	42-62 mμ	0.8-1.2	8.6-12.9 μ	0.17-0.25	(0.82)				
11 Nematoda								0.2-20 M	0.7-17.8	4-107 m	
12 Monhystera	0.2-0.3	16.0	1.4-2.2 μ	6.1-8.3	300-450 μ	1.3-1.7	0.83				
13 Plectus	0.5-1.0	16.0	2.9-5.8 μ	4.8-6.8	600-1200 μ	1-1.4	0.83				
14 Dorylaimus	0.5-56	16.0	1.9-216 μ	2.4-5.3	400-45,000 μ	0.5-1.1	0.83				
15 Annelida								50-2000	1.6	0.5 m	
16 Lumbricus terrestris (earthworm)	500	17-20	0.14 m	0.29	0.03	0.06	(0.82)				
17	5000	20-23	1.4 m	0.29	0.3	0.06	(0.82)				
18	1200	13.0	0.42 m	0.35	0.09	0.07	(0.82)				
19 Mollusca								0-8500	0-50	0-15 m	
20 Helix aspersa (garden snail)	10,000	10.0	2.1 m	0.21	0.43	0.04	(0.82)				
21	10,000	20.0	4.2 m	0.42	0.88	0.09	(0.82)				
22 Arthropoda											
23 Crustacea								0-200	0-1.2	0-2.4 m	
24 Talorchestia megalopthalma	120	12-13	0.1 m	0.87	0.02	0.18					
25	390	12-13	0.16 m	0.40	0.03	0.08					
26	110	22-23	0.18 m	1.6	0.04	0.34	(0.82)				
27	270	22-23	0.28 m	1.0	0.06	0.22					
28 Acari (mites)											
29 Oribatei								2000-120,000	4.5	6.7 m	
30 Euzetes atterimus	0.25	14.5	150-190 mμ	0.6-0.8	30-40 μ	0.12-0.16	(0.82)		0.07-0.8	0.1-1.2 m	
31 Notaspis coleoptratus	0.03	11.3	48 mμ	1.6	10 μ	0.33	(0.82)				
32 Parasitiformes								200-7400	0.09-0.2	0.1-0.3 m	
33 Macrocheles sp	0.25	12.0	480 mμ	1.9	100 μ	0.4	(0.82)				
34 Araneae (spiders)								175-640	0.64	0.4-1.4 m	
35 Lycosa sp	15.1	13.0	33 μ	2.2	6900 μ	0.45	(0.82)				
36 Opiliones								1.6-38	0.005-0.15	0.02-0.5 m	
37 Nemastoma sp	3.8	13.0	9.2 μ	2.4	1900 μ	0.5					
38 Insecta											
39 Collembola								40-40,000	6.8	27-46 m	
40 Pogonognathus plumbens	1.3-2.5	13.0	6.5-9.3 μ	3.7-5.0	1400-1900 μ	0.77-1.0					
41 Orchesella flavescens	1.8-3.5	13.0	5.3-11.7 μ	2.9-3.3	1100-2400 μ	0.61-0.69					
42 Diptera									1.0	1.3 m	
43 Tipula sp (larva)	275	13.0	285 μ	1.0	0.06	0.21	(0.81)				
44	605	13.0	500 μ	0.82	0.1	0.17	(0.82)				
45 Coleoptera									3.8	6.1 m	
46 Carabus nemoralis (ground beetle)	645	13.0	765 μ	1.2	0.16	0.25	(0.82)				
47 Epaphius secalis (ground beetle)	1.2-2.2	13.0	7-9.8 μ	5.9	1.5-2.0 m	1.2	(0.82)				
48 Notiophilus biguttatus (ground beetle)	7.5	13.0	36 μ	4.8	7.6 m	0.88	(0.82)				
49 Staphylinus olens (rove beetle)	245	13.0	285 μ	1.1	0.06	0.24	(0.82)				

/1/ Temperature used in determining values in columns D-G. Values in column K are reduced to the common standard of 16°C according to Krogh's curve. /2/ Kilocalories. /3/ CO₂ liberated ÷ O₂ consumed. Values in parentheses are assumed. /4/ Kilocalories per individual per hour. /5/ Milliliters per individual per hour. /6/ Assuming a water content of 75% of the fresh weight.

237. BIOCHEMICAL ACTIVITIES, PROCESSES, PRODUCTS, AND USES: MICROORGANISMS USEFUL TO MAN

This table lists only a few of the vast number of microbial reactions that are known, and is merely representative of types of processes used commercially. Most processes are patented; and recent information on yields and process modifications is not generally available. Industry is continually seeking better yielding strains of microorganisms through selection and mutation.

Part I: GENERAL ORGANIC COMPOUNDS

	Product	Microorganism	Substrate ¹	Type of Culture ¹	pH	Temp °C	Time da	Yield	Industrial Uses
1	Acetone-butanol	<i>Clostridium saccharoacetobutylicum</i> , and others	Molasses diluted to 5-7% sugar, with addition of NH_3 compounds and CaHPO_4 as required.	Anaer.	5.0-7.0	29-34	1.7-2	28-33% mixed solvents (sugar basis); 74% butanol, 23% acetone, 4% ethanol.	Solvents; chemical manufacturing.
2	2,3-Butanediol	<i>Bacillus polymyxa</i> ; <i>Aerobacter aerogenes</i>	Grain mash, or starch plus nutrients, or sugars plus nutrients.	Preferably aer.	6.2	33	1.3-3	26-30% weight of carbohydrates.	Solvent; humectant; chemical intermediate.
3	Dihydroxyacetone	<i>Acetobacter suboxydans</i>	5% glycerol, 0.5% yeast extract, 0.25% KH_2PO_4 .	Aer., sub. or surf.	5.5-7.0	28-30	3-10	90% of theory.	Fine chemical.
4	Ethanol	<i>Saccharomyces cerevisiae</i>	Molasses diluted to 12% sugar. Amm. sulfate or phosphate added as nutrients.	Aer. in early stages only	4.0-4.5	21-35	2.1	90% of theory based on fermentable sugar.	Solvent; fuel; chemical intermediate.
5	Glycerol	<i>S. ellipsoideus</i> var. Cal. wine yeast; <i>S. cerevisiae</i>	Molasses diluted to 17.5-20% sugar. Soda ash to 5% of mash added during fermentation.	Aer. in early stages only	7-8	30-32	5	20-25% of theory based on fermentable sugar.	Solvent; explosives, drugs and cosmetics; humectant.
6	Citric acid	<i>Aspergillus niger</i> , or <i>A. wentii</i>	10-20% sucrose, or purified molasses mashes plus nutrients.	Sub., aer. or surf.	3.0-4.1	25-30	3-10	60-90% based on sugar.	Food products, medicinal citrates; in blood for transfusion.
7	Fumaric acid	<i>Rhizopus nigricans</i>	5-10% invert sugar, plus nutrient salts and CaCO_3 .	Sub., aer.	5-6	33	4	58-64% based on sugar utilized.	Manufacture of alkyd resins, wetting agents.
8	Gluconic acid	<i>Aspergillus niger</i> , strain 67	Corn sugar, MgSO_4 , KH_2PO_4 , $(\text{NH}_4)_2\text{HPO}_4$, CaCO_3 . Glucose conc. 15.2 g/100 ml.	Sub., aer.	5.0	30	1	93-97% based on glucose utilized.	Pharmaceutical products.
9	2-Keto-gluconic acid	<i>Pseudomonas</i> spp	Glucose, gluconic acid.	Aer.	4.5-7	30-35	1.4-1.5	90%.	Intermediate for D-arabascorbic acid.
10	5-Keto-gluconic acid	<i>Acetobacter suboxydans</i>	Glucose.	Aer.	4.5-7	30-35	1.5-2.5	90-95%.	Intermediate for tartaric acid.
11	Itaconic acid	<i>Aspergillus terreus</i>	6.6-27.5% glucose or sucrose (molasses) plus $(\text{NH}_4)_2\text{SO}_4$, MgSO_4 , corn steep liquor	Sub. or surf., aer.	1.8-2.2	35	2-3	38-60% based on sugar.	Manufacture of alkyd resins, wetting agents.
12	Kojic acid	<i>A. flavus</i>	Sugars plus mineral nutrients.	Aer.	2.0-3.5	29-35	12	45-60% based on sugar.	No uses developed.
13	Lactic acid	<i>Lactobacillus delbrückii</i>	Acid hydrolyzed corn starch or whey, plus nutrients and CaCO_3 .	Anaer.	5.5-6.5	45	5-10	93-94% based on sugar.	Food products, textile and laundry, chem. mfg., deliming hides.
14	Bacitracin(s)	<i>Bacillus licheniformis</i>	Dextrose, sucrose or starch, plus soybean or peanut meal or other protein.	Sub., aer.	6.2-7.7	37	2-3	1.5 grams per liter.	Active against Gram-pos. bacteria topically.
15	Carbomycin (Magnamycin)	<i>Streptomyces halstedii</i>	Media of organic composition.	Sub., aer.	6-8		3-5	100 mg per liter.	Active against some Gram-pos. bact., rickettsia, large viruses.
16	Chloramphenicol (Chloromycetin)	<i>S. venezuelae</i>	1% maltose, 0.5% casamino acids, 0.5% distillers' solubles, 0.5% NaCl.	Sub., aer.	6.7	23-27	3-6	170 mg per liter.	Same as aureomycin.
17	Chlortetracycline (Aureomycin)	<i>S. aureofaciens</i>	0.5-5.0% starch or monosaccharoses; amino acids, casein, fish meal, soybean meal, urea, nitrates, NH_3 compounds or corn steep liquor; inorg. salts of K, Ca, Mg, Fe, S, Cu, Mn, and Zn.	Sub., aer.	6.0-7.0	26-28	1-3	500-1300 mg per liter.	Effective orally against Gram-pos. and some Gram-neg. bacteria, some rickettsia and some viruses.
18	Cycloheximide (Actidione)	<i>S. griseus</i>	Glucose, salts, soybean meal, and butyl fermentation residue.	Aer.	6-8	24	3-5	80-250 mg per liter.	Antibiotic; yeasts, fungi, esp. plant disease fungi.
19	Erythromycin (Ilotycin)	<i>S. erythreus</i>	Glucose, soybean meal, corn steep liquor.	Sub., aer.	6.4-7.2	26-30	3-5	350 mg per liter.	Same as aureomycin.
20	Fumagillin (Phagopedin Sigma)	<i>Aspergillus fumigatus</i>	Dextrin and corn steep liquor.	Sub., aer.	6.5-7.5		1.5-4	300 mg per liter.	Antibiotic.
21	Neomycin (complex)	<i>Streptomyces fradiae</i>	Glucose, soya peptone, meat extract, NaCl, ZnSO_4 .	Sub., aer.	6.5-6.8	24-30	3.8-6	2-3 grams per liter.	Active against Gram-pos. and Gram-neg. bacteria.
22	Oxytetracycline (Terramycin)	<i>S. rimosus</i>	Soybean meal, starch, casein digest, salts.	Sub., aer.	7.0-8.0	24-30	2	>1 gram per liter.	Broad spectrum antibiotic.
23	Penicillin	<i>Penicillium chrysogenum</i> Q176 or derived mutants	Corn steep liquor, lactose, dextrose, animal or vegetable oil, salts, phenylacetic acid.	Sub., aer.	5.5-7.5	23-25	2-6	1000-3000 International Units per ml.	Active against many Gram-pos. organisms.
24	Polymyxins	<i>Bacillus polymyxa</i>	Glucose, yeast extract, salts.	Sub., aer.	6.3-7.9	25	5	163-358 units polymyxin D per ml.	Active against Gram-neg. bacteria.
25	Streptomycin	<i>Streptomyces griseus</i> ²	Glucose, soybean meal, corn steep liquor, NaCl, and animal or vegetable oil.	Sub., aer.	6.0-7.5	24-30	3-6	150-900 mg per liter.	Active against many bacteria, particularly Myco. tuberculosis.
26	Viomycin (Vinactin)	<i>S. floridae</i> or <i>S. puniceus</i>	Glucose, hydrolyzed casein, yeast hydrolyzate, salts.	Sub., aer.	6.0-8.0	24-26	3-6	600 mg per liter.	Active against Myco. tuberculosis.
27	Bacterial amylase	<i>Bacillus subtilis</i>	Vegetable protein plus sugar for surf.; starch, cereal grain and protein for sub.	Surf., aer., or sub., aer.	6.5-7.0	30-40	1-3	400-500 grams amylase concentrate from 100 liters culture.	Modified starches; sizing paper; desizing textiles.

28	Bacterial protease	<i>B. subtilis</i>	1% protein, 6% carbohydrate, salts.	Surf., aer.	6.5-7.0	37	3-5		Bating hides; desizing fibers; spot remover; tenderizing meat.
29	Pectinases	<i>Aspergillus wentii</i> or <i>A. aureus</i> (Nakazawa)	1000 kg bran plus 800 liters H ₂ O. Inoculate with 100 liters spore suspension.	Aer.		33-37	2-3	Aqueous extract of culture adsorbed on bran from coffee bean husk.	Clarifying agents in fruit juice industries.
30	11- γ -Hydroxyprogesterone	<i>Rhizopus arrhizus</i> , <i>R. nigricans</i> , others	Progesterone, plus lactalbumin digest, corn steep liquor, glucose.	Aer.	4.4-6	24-28	2-3	10-95%.	Intermediate for 17- γ -hydroxycorticosterone.
31	Dextran	<i>Leuconostoc mesenteroides</i>	Sucrose plus nutrients.	Anaer.		20-30	1-5	10-40% of sucrose used.	Stabilizer in food products; blood plasma substitute.
32	Sorbose	<i>Acetobacter suboxydans</i>	25% sorbitol plus yeast extract or corn steep liquor.	Aer., sub., or surf.	5.1-6.8	28-30	3-10	90-95% of theory.	Manufacture of ascorbic acid.
33	Cobalamin	<i>Streptomyces olivaceus</i> ; <i>Propionibacterium freudenreichii</i>	Distillers' solubles, dextrose, CaCO ₃ , CoCl ₂ .	Sub., aer. agitation.	6.5-8.0	27-29	3-5	1.2 mg per liter, average.	Pernicious anemia; food and feed supplementation.
34	Ergosterol	<i>Saccharomyces carlsbergensis</i>	Saccharine materials with nutrients.	Aer.	7.0-7.5	25	1-2	2-2.7% of weight of yeast.	Manufacture vitamin D.
35	Riboflavin ³	<i>Ermenthedium ashbyii</i> , <i>Ashbya gossypii</i> , and others	For <i>E. ashbyii</i> , carbohydrates and protein; for <i>A. gossypii</i> , glucose, corn steep and animal steep liquor.	Sub., aer.	4.5-7.5	27-30	5-10	0.5-2.5 grams per liter.	Food and feed supplementation.

/1/ Sub.=submerged culture; surf.=surface culture; aer=aerobic; anaer.=anaerobic. /2/ Improved strains obtained by exposing organism to UV light or nitrogen mustard. /3/ See U.S. Patent 2,605,210.

Part II: FOODS AND BEVERAGES

Product	Microorganism	Method of Preparation	Factors Influencing Reaction	Function of Microorganism
1 Acidophilus milk	<i>Lactobacillus acidophilus</i>	Fresh, whole milk sterilized at 120°C for 15 min is cooled and inoculated with the organism.	Microaerophilic, pH 6.6, 35-37°C, 20-48 hr.	Produces lactic acid from milk sugar ¹ .
Cheese				
2 Camembert and Brie types	<i>Penicillium camemberti</i> Thom and others	Curd cut into cakes 3-4 cm thick, containing 55-60% H ₂ O and salted on surface.	4 wk at 10-16°C, in a ripening room at 88% relative humidity.	Mold grows on cheese surface, gradually softening whole mass of curd.
3 Roquefort and Gorgonzola types	<i>P. roqueforti</i>	Raw curd pressed to leave irregular cracks and channels; inoculated with mold grown on bread.	Partially aerobic. Aerated during ripening at 9°C by piercing with wires.	Produces caproic, caprylic, other acids imparting characteristic flavor.
4 Pickles	Mixed natural lactic acid organisms, including <i>Lactobacillus plantarum</i>	Cucumbers in tanks allowed to undergo spontaneous lactic fermentation in salt brine. For dill pickles, dill spices added before fermentation. For others, salt is leached, and pickles packed with vinegar, sugar, spices, etc.	Salt concentration and availability of O ₂ affect rate and kind of fermentation. Optimum temp is 21-27°C.	Converts fermentable substances, forming particularly lactic acid. Final titratable acidity, as lactic acid, 0.5-1.0%, pH = 3.5-3.8.
5 Sauerkraut	Same as for pickles	Shredded cabbage placed in vats with salt. Undergoes spontaneous lactic fermentation.	Anaerobic fermentation. Optimum temp 16-24°C.	Converts fermentable substances into lactic acid, mainly, plus acetic acid and ethanol. Final acidity, as lactic, 1.5-2.0%.
6 Vinegar	<i>Acetobacter aceti</i> , <i>A. pastorianum</i> and other <i>Acetobacter</i> spp	Alcoholic solutions (e.g., wine, cider) derived from fermentation of grapes, apples, or grain are "acetified" by acetic acid bacteria.	Aerobic requiring 8-10 da at 28-40°C, or less depending on process conditions.	Alcohol oxidized to acetic acid, 5% acid being formed from approximately 5% alcohol.
7 Yeast, bakers'	<i>Saccharomyces cerevisiae</i> (selected bakers' strains)	Molasses solutions with ammonium salts, phosphates, and Mg salts seeded with pure yeasts strains. Increments of medium added frequently as nutrients are exhausted.	Very vigorous aeration throughout process. pH 3.4-4.5. Temp 24-30°C. Growth complete in 11 hr.	Converts 100 parts molasses to equivalent of 100 parts pressed yeast (27% dry matter).
8 Beer	<i>S. cerevisiae</i> or <i>S. carlsbergensis</i>	Barley malt and starch adjuncts mixed with warm water. After enzymic starch conversion, wort is filtered, then boiled with hops, and finally fermented with yeast.	Aerobic in early stages, but quickly becomes anaerobic. Temp 8-12°C ² . pH at start 5.0-5.4; at end 4.0-4.8. Primary fermentation lasts 5-9 da. Optimum pH 4.0-4.7. Initial temp 21°C rising to final temp of 35.5. Fermentation lasts 3-7 da.	Converts sugar into alcohol and CO ₂ ; produces changes in proteins and other minor constituents which modify flavor.
9 Rum	<i>S. cerevisiae</i> or other yeasts	Blackstrap molasses containing 12-14% fermentable sugar. Ammonium sulfate and occasionally phosphates may be added as nutrients. Distilled after fermentation.	Optimum pH 4.0-5.0. Initial temp 26°C. Fermentation completed in 72 hrs.	Sugar converted to alcohol which is then removed by distillation.
10 Whisky, Scotch	<i>S. cerevisiae</i> (generally a top yeast)	Grain mash cooked, saccharified with peated malt and fermented. Batch distilled and distillate aged in oak casks at least 3 yr; then blended with grain whiskey.	Same as for Scotch whisky.	Produces alcohol and congenic substances (acids, esters, various alcohols) which with the peated malt give characteristic Scotch flavor.
11 Whiskey, bourbon	<i>S. cerevisiae</i>	Grain mash consistency of corn (at least 51%); generally with rye, cooked and saccharified with malt and fermented. Distillate, between 110-130° proof, matured in charred oak barrels.		Same as for Scotch whisky, but the flavor is characteristic of bourbon whiskey.
12 Wine	<i>S. ellipsoideus</i> , various strains	Grape must with sugar concentration up to 22° Balling is sulfited to reduce rate of fermentation. Allowed to ferment with special strain of yeast, or with yeast naturally present on the grape. Primary fermentation succeeded by a period of storage for maturation.	Aerobic in early stages, but mainly anaerobic later. Temp below 29.4°C, but varies according to local conditions, yeast strain, and type of wine. Fermentation lasts 7-11 da.	Converts sugar into alcohol, and also produces changes in minor constituents which modify flavor and bouquet. Amount of alcohol varies according to type of wine.

/1/ Lactic acid plus large quantities of organism produced are used for various disorders of the gastrointestinal tract. /2/ 14-20°C with *S. cerevisiae*.

238. BASAL AND RESTING ENERGY METABOLISM: VERTEBRATES

Animal	Stage	Approximate Age		Body Weight		Body Surface Areal		Resting Metabolism ²				Oxygen Consumption		Basal Metabolism				Oxygen Consumption	
				kg		sq m		Cal/kg/da		Cal/sq m/da		liters/kg/da		Cal/kg/da		Cal/sq m/da		liters/kg/da	
		♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
1 Man	Adult			65	56	1.83	1.65							25.5	23.2	910	790		
2 Baboon	Adult			6.2		0.40								48		760			
3	Young	1.8 mo		70	60	1.4	1.3	43.8	51.1	2190	2385	9.1	10.6						
4 Beef cattle	Half-grown	11 mo		300	250	3.2	2.9	25.6	26.3	2420	2295	5.3	5.5		18.2		1595		3.8
5	Adult	1.7 yr		500	400	4.2	3.7	21.2	21.1	2515	2270	4.4	4.4		15.2		1635		3.2
6 Cat	Adult			3.0		0.2								50		750			
7 Chimpanzee	Adult			38		1.1								29.2		980			
8	Young	6 mo			150		2.4		34.4		2100		7.1						
9 Dairy cattle	Half-grown	1.2 yr			300		3.6		26.0		2170		5.4						
10	Adult	2 yr			500		5.0		21.1		2180		4.4						
11 Dog	Adult			15.5	11.7	0.65	0.58							33.5	38.5	800	770		
12 Elephant	Adult			3670		23.8								13.3		2060			
13 Elephant, small	Adult			1360		13.7								11.8		1170			
14	Young			2				130	125										
15 Goat	Half-grown			20				63	54										
16	Adult			70				42	34										
17	Young	30 da		0.2		0.029		115	120	780	805	23	24	110	110	735	765	23	24
18 Guinea pig	Half-grown	82 da	87 da	0.4		0.046		90	95	800	825	29	19	85	90	755	790	18	19
19	Adult	290 da	270 da	0.8		0.071		63	68	710	765	13	14	60	63	675	710	13	13
20	Young	2.8 mo	2.9 mo	200		2.8		32.2	32.7	2280	2320	6.7	6.8						
21 Horse	Half-grown	9.5 mo	8.5 mo	350		4.0		24.6	25.3	2150	2210	5.0	5.2						
22	Adult	4.2 yr	2.8 yr	650		5.9		25.2	24.7	2770	2710	5.2	5.1						
23 Macaque	Adult			4.2		0.31								49.3		675			
24 Marmot	Adult			2.6		0.18								28.3		420			
25 Monkey, rhesus	Adult			3.2		0.26								48.4		610			
26 Mouse, albino	Adult			0.02		0.005								170		525			
27 Mouse, dwarf	Adult			0.008		0.004								125		280			
28 Mouse, obese	Adult			0.06		0.01								130		550			
29	Young	4 mo		200		2.9		39.2		2700		8.1							
30 Mule	Half-grown	13 mo		400		4.5		30.6		2705		6.3							
31	Adult	38 mo		600		5.8		26.4		2710		5.5							
32 Pony, shetland	Adult			280		4.4								16.7		1060			
33 Rabbit	Adult			3.5		0.2								47		810			
34	Young	29 da		0.05		0.013		280		1085		60		240		930		51	
35 Rat	Half-grown	50 da	60 da	0.15		0.026		195	165	1120	970	39	34	160	155	930	890	34	33
36	Adult	60 da	120 da	0.2		0.031		155	135	1000	870	32	28	140	120	905	760	30	25
37 Sheep	Adult			49.5	42.7	1.10	0.95							26.3	25.7	1180	1160		
38	Young	9.4 mo	8.3 mo	75		1.5		37.3	40.5	1880	2040	7.7	8.4	30.9	30.2	1550	1520	6.4	6.3
39 Swine	Half-grown	1.3 yr	1.1 yr	150		2.3		28.9	25.1	1880	1625	6.0	5.2	21.9	18.7	1420	1210	4.5	3.9
40	Adult	2.1 yr		250		3.2		23.7	17.8	1860	1390	4.9	3.7	17.4	14.1	1360	1100	3.6	2.9
41 Birds, wild	Adult			3.0		0.2								57		830			
42 Canary	Adult			0.016		0.006								310		760			
43	Young	4 wk		0.25	0.2	0.04	0.03	195	210	1220	1230	40	43						
44 Chicken	Half-grown	13 wk		1.1	0.9	0.11	0.1	105	100	1020	900	21	20	90	90	870	830	19	19
45	Adult	25 wk		2.6	2.0	0.21	0.17	95	75	1160	880	19	16	85	70	1075	800	18	15
46 Dove, ring	Adult			0.15		0.03								130		700			
47 Duck	Adult			0.93		0.1								90		855			
48 Goose	Adult			5.0	3.3	0.29	0.23							54	61	940	880		
49 Parakeet	Adult			0.03		0.009								225		690			
50 Pigeon	Adult			0.28		0.04								100		670			
51 Lizard				1.2		0.11								2.5		29			
52 Turtle				0.14		0.02								11.4		64			
53 Frog				to 0.05												130			
54 Toad				to 0.05												130			
55 Fish				to 0.25												33			
56 Fish, sturgeon				1400		11.8								0.3		31			

/1/ Surface area in sq m calculated from $k \times W^{0.67}$, or, in sq cm, from the following equations (W =body weight in grams): man, $3.81 W^{0.425} \times H^{0.725}$ (where H =height in cm); baboon, $11.7 W^{0.667}$; chimpanzee, $10 W^{0.667}$; dog, $11.2 W^{0.667}$; guinea pig, $9.85 W^{0.64}$; monkey, rhesus, $11.7 W^{0.667}$; mouse, $15.18 W^{0.458}$; rabbit, $56.33 W^{0.436}$; sheep, $8.5 W^{0.667}$; chicken, $8.19 W^{0.705}$; reptiles, amphibians, fish, $9 W^{0.67}$. Surface area in sq m (W =body weight in kg): beef cattle, $0.13 W^{0.56}$; dairy cattle, $0.15 W^{0.56}$; horse, $0.1 W^{0.63}$; mule, $0.1 W^{0.636}$; rat, $0.0011 W^{0.63}$ (W in grams); swine, $0.097 W^{0.633}$.

/2/ Resting metabolism refers to heat production when animal is at rest, although neither in a strictly thermo-neutral environment, nor in a post-absorptive state. Cattle, goats, swine, and chickens were measured in a recumbent position. Resting metabolism, as thus defined, is considerably greater than basal metabolism, exact values depending on nature of diet, time after feeding, and environmental temperature.

239. BASAL METABOLISM: MAN

Values are smoothed means of basal Calories per sq m per hr from the three largest and most authoritative sets of original data, representing a total of 4016 measurements. The three sets of data used are: (1) The Mayo Foundation Standards of Boothby, Berkson and Dunn, based upon 639 males and 828 females; (2) the British measurements of Robertson and Reid, based upon 987 males and 1323 females; (3) The Carnegie Nutrition Laboratory data of Harris and Benedict, based upon 136 males and 103 females. The height-weight formula of DuBois and DuBois was used in computing the sq m of body surface area: $SA = 0.007184 \times W^{0.425} \times H^{0.725}$, where SA is the surface area in square meters, W is the body weight in kilograms and H is the height in centimeters. Ranges, given in parentheses, are calculated from an average coefficient of variation¹ of 6.9% and represent estimate "b" of the 95% range. Somewhat higher values are to be expected on first tests (i.e., on persons not accustomed to the procedures). For comparison of these standards with previous American and other important standards, see table below.

Age yr		Males	Females	Age yr		Males	Females
		Cal/sq m/hr				Cal/sq m/hr	
1	Three	60.1(51.8-68.3)	54.5(47.0-62.0)	24	Twenty-six	38.2(32.9-43.5)	35.0(30.2-39.8)
2	Four	57.9(49.9-65.9)	53.9(46.5-61.3)	25	Twenty-seven	38.0(32.8-43.2)	35.0(30.2-39.8)
3	Five	56.3(48.5-64.1)	53.0(45.7-60.3)	26	Twenty-eight	37.8(32.6-43.0)	35.0(30.2-39.8)
4	Six	54.0(46.5-61.5)	51.2(44.1-58.3)	27	Twenty-nine	37.7(32.5-42.9)	35.0(30.2-39.8)
5	Seven	52.3(45.1-59.5)	49.7(42.8-56.6)	28	Thirty	37.6(32.4-42.8)	35.0(30.2-39.8)
6	Eight	50.8(43.8-57.8)	48.0(41.4-54.6)	29	Thirty-one	37.4(32.2-42.6)	35.0(30.2-39.8)
7	Nine	49.5(42.7-56.3)	46.2(39.8-52.6)	30	Thirty-two	37.2(32.1-42.3)	34.9(30.1-39.7)
8	Ten	47.7(41.1-54.3)	44.9(38.7-51.1)	31	Thirty-three	37.1(32.0-42.2)	34.9(30.1-39.7)
9	Eleven	46.5(40.1-52.9)	44.1(38.0-50.2)	32	Thirty-four	37.0(31.9-42.1)	34.9(30.1-39.7)
10	Twelve	45.3(39.0-51.6)	42.0(36.2-47.8)	33	Thirty-five	36.9(31.8-42.0)	34.8(30.0-39.6)
11	Thirteen	44.5(38.4-50.6)	40.5(34.9-46.1)	34	Thirty-six	36.8(31.7-41.9)	34.7(29.9-39.5)
12	Fourteen	43.8(37.8-49.8)	39.2(33.8-44.6)	35	Thirty-seven	36.7(31.6-41.8)	34.6(29.8-39.4)
13	Fifteen	43.7(37.7-49.7)	38.3(33.0-43.6)	36	Thirty-eight	36.7(31.6-41.8)	34.5(29.7-39.3)
14	Sixteen	42.9(37.0-48.8)	37.7(32.5-42.9)	37	Thirty-nine	36.6(31.5-41.7)	34.4(29.7-39.1)
15	Seventeen	41.9(36.1-47.7)	36.2(31.2-41.2)	38	Forty	36.5(31.5-41.5)	34.3(29.6-39.0)
16	Eighteen	40.5(34.9-46.1)	35.7(30.8-40.6)	39	Forty-five	36.3(31.3-41.3)	33.9(29.2-38.6)
17	Nineteen	40.1(34.6-45.6)	35.4(30.5-40.3)	40	Fifty	36.0(31.0-40.0)	33.4(28.8-38.0)
18	Twenty	39.8(34.3-45.3)	35.3(30.4-40.2)	41	Fifty-five	35.4(30.5-40.3)	32.9(28.4-37.4)
19	Twenty-one	39.4(34.0-44.8)	35.2(30.3-40.1)	42	Sixty	34.8(30.0-39.6)	32.4(27.9-36.9)
20	Twenty-two	39.2(33.8-44.6)	35.2(30.3-40.1)	43	Sixty-five	34.0(29.3-38.7)	31.8(27.4-36.2)
21	Twenty-three	39.0(33.6-44.4)	35.2(30.3-40.1)	44	Seventy	33.1(28.5-37.7)	31.3(27.0-35.6)
22	Twenty-four	38.7(33.4-44.0)	35.1(30.3-39.9)	45	Seventy-five and above		
23	Twenty-five	38.4(33.1-43.7)	35.1(30.3-39.9)			31.8(27.4-36.2)	31.1(26.8-35.4) ²

/1/ Coefficient of variation = 6.9 = average of values from five sources. /2/ Value and range extrapolated from smoothed curve.

240. COMPARATIVE STANDARDS OF BASAL METABOLISM: MAN

Column F is the standard commonly employed heretofore in America. The underlying measurements include many first tests (on persons unaccustomed to the procedure). Values are accordingly high -- the highest of the standards. Values in column D, the British standard, are based on the lowest of repeated measurements on trained persons under rigorously basal conditions. Values in column E are based on measurements on well trained children and are generally the lowest of those given for children. Adult values in columns B and C are so similar that either standard can be used safely in clinical medicine. For children, choice between columns E or C and columns B or D will depend on the experience of the testing laboratory. Some laboratories tend to find higher basal values and some laboratories, lower. Each laboratory may accordingly develop its own standard. A variation of as much as 14% above or below the standard may occur in healthy persons (estimate "b" or "d" of the ordinary range).

Age yr	Boothby ¹ 1952		Fleisch ² 1951		Robertson and Reid ³ 1952		Lewis, Duval and Illiff, ⁴ 1943		Boothby, Berkson and Dunn, ⁵ 1936	
	Cal/sq m/hr		Cal/sq m/hr		Cal/sq m/hr		Cal/sq m/hr		Cal/sq m/hr	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
(A)	(B)		(C)		(D)		(E)		(F)	
1	Two		52.4	52.4			56.9	52.9		
2	Four	57.9	53.9	50.3	49.8	57.9	53.9	52.6	49.9	
3	Six	54.0	51.2	48.3	47.0	54.2	51.8	49.6	46.9	53.0
4	Eight	50.8	48.0	46.3	43.8	50.1	48.4	46.6	44.0	51.5
5	Ten	47.7	44.9	44.0	42.5	46.6	44.3	43.6	41.4	48.0
6	Twelve	45.3	42.0	42.5	41.3	43.8	40.6	41.5	39.7	46.8
7	Fourteen	43.8	39.2	42.1	39.2	41.8	37.8	41.1	36.8	46.4
8	Sixteen	42.0	37.2	41.4	36.9	40.3	36.0			45.5
9	Eighteen	40.8	35.8	40.0	35.9	39.2	34.9			42.9
10	Twenty	39.9	35.3	38.6	35.3	38.4	34.3			41.6
11	Twenty-five	38.4	35.1	37.5	35.2	37.1	34.0			40.3
12	Thirty	37.6	35.0	36.8	35.1	36.4	34.1			39.6
13	Thirty-five	36.9	34.8	36.5	35.0	35.9	33.5			38.9
14	Forty	36.5	34.3	36.3	34.9	35.5	32.6			38.3
15	Forty-five	36.3	33.9	36.2	34.5	34.3 ⁶	32.4 ⁶			37.6
16	Fifty	36.0	33.4	35.8	33.9	33.9 ⁶	32.1 ⁶			37.0
17	Fifty-five	35.4	32.9	35.4	33.3	33.6 ⁶	31.8 ⁶			36.3
18	Sixty	34.8	32.4	34.9	32.7	33.2 ⁶	31.4 ⁶			35.7
19	Sixty-five	34.0	31.8	34.4	32.2	32.8 ⁶	31.2 ⁶			35.1 ⁷
20	Seventy	33.1	31.3	33.8	31.7	32.6 ⁶	30.8 ⁶			34.5 ⁷
21	Seventy-five ⁸	31.8	31.1 ⁹	33.2	31.3	32.0	30.5 ⁹			33.4 ⁷

/1/ These are the values used in the top table; they are based on values in cols. D, F and values from Harris and Benedict, 1919. /2/ Based on values from 24 reports in the literature, including those in cols. E, F, of this table and values from Harris and Benedict, 1919. /3/ The British standard. These values constitute part of the basis for those in col. B. /4/ These values constitute part of the basis for those in col. C. /5/ These values are part of the basis for those in cols. B and C. /6/ Interpolated. Original data given for pentades 40-44, 45-49, etc. /7/ Extrapolated by authors. /8/ Values are for age 75 or over. /9/ Extrapolated.

241. TISSUE OXYGEN CONSUMPTION: ANIMALS

Oxygen consumed by tissue in a buffered medium is measured in a closed chamber at approximately 1 atm. pressure and at 37°C. Further definition of the medium is given in the key below; where only the substrate is named the medium contains that substrate in Ringer solution. The oxidation quotient ($-Q_{O_2}$) is expressed in cu mm O_2 per mg dry-weight tissue in one hour. A = serum; B = Ringer glucose; C = saline; D = Ringer phosphate; E = Ringer solution; F = horse serum; G = horse serum glucose; H = glutamate; I = lactate; J = succinate; K = pyruvate; L = glucose; M = no substrate added; N = alanine; O = butyrate.

Tissue	Me- dium	$-Q_{O_2}$	Tissue	Me- dium	$-Q_{O_2}$	Tissue	Me- dium	$-Q_{O_2}$	Tissue	Me- dium	$-Q_{O_2}$	Tissue	Me- dium	$-Q_{O_2}$
Man			Rat (concluded)			Mouse (concluded)			Cat (concluded)			Cattle (concluded)		
1 Cerebral cortex	B	6.0-10.3	55 Mammary, 15-22 da	B	10.0	108 Ovary	A	9.0	160 Cerebral cortex	B	8.5-12.2	211 Liver	D ¹	8.2
2 Decidua	A	2.5	56 Lactation	B	10.0	109 Placenta, 0.4 mg	A	7.5	161 Kidney cortex	D ¹	22.7	212 Cow	B	2.6
3 Lung, embryo	B	3.7	57 2 da after weaning	B	5.5	110 10.9-13.7 mg	A	6.4	162 Liver	D ¹	13.2	213 Lung	D ¹	4.3
4 Lymph nodes	B	3.8-5.9	58 50 da	B	3.4	111 Pituitary	A	8.0	163 Lung	D ¹	3.9	214 Retina, ox	B	10.7
5 Mucosa, gastric	B	9.6	59 Adult	B	9.0	112 Skin, newborn	B	6.1	164 Lung	B	3.9	215 Sperm	D	6.6
6 Muscle, smooth, gastric	B	1.3	60 Mucosa, colon	B	2.5-4.9	113 Spleen	D ¹	16.9	165 Medulla	B	3.5	216 Sperm	F	11.2
7 Uterine	B	0.6	61 Duodenal	B	3.4-14.6	Guinea Pig			166 Muscle, heart	B	2.5	217 Sperm	G	12.8
8 Salivary gland	B	6.3	62 Gastric	B	8.8	114 Adrenal	A	6.0	167 Smooth, intest.	B	1.4	218 Sperm, epididymal	D	2.6
9 Skin, adult	B	2.1	63 Ileum	B	7.2	115 Brain cortex	D ¹	27.3	168 Pancreas	B	5.8	219 Spleen	D ¹	4.4
10 Fetus	D	1.8	64 Jejunum	B	3.7	116 Cerebral cortex	C, L ⁹	6.9	169 Salivary, acetyl-	B	13.6	220 Thyroid, calf	B	2.6
11 Sperm	D	0.54	65 Muscle, diaphragm	C, E	4.1-5.9	117 Cerebral cortex	C, L ⁹	11.7	choline stimulation	B	13.6	Swine		
12 Tonsil	B	5.1	66 Diaphragm	A	5.9	118 Epithelium ¹⁰	B	6.1	170 Eserine + AcCH	B	22.7	Cerebral cortex	E	5.5
Rat			67 Heart	B	3.8-10.4	119 Of castrate	D ¹	2.8	171 Resting	B	10.3	221 29-60 da fetus	E	6.5
13 Adrenal	A	10.0	68 Skeletal	B	2.3-3.1	120 Kidney cortex	D ¹	31.8	172 Spinal cord	B	1.3	222 99 da fetus	E	8.5
14 Brain cortex	D ¹	26.3	69 Smooth, gastric	B	3.5	121 Liver	D ¹	13.0	173 Spleen	D ¹	8.4	223 Birth to adult	B	17.7
15 Cerebral cortex	M	2.9	70 Smooth, intest.	B	6.3	122 Liver	C	8.1	Dog			224 Retina	B	2.1
16 Cerebral cortex	L	10.8	71 Smooth, intest.	C	7.1	123 Liver	E	5.0	174 Brain cortex	D ¹	21.2	225 Thyroid, hog	B	2.1
17 Cerebral cortex	H	8.0	72 Ovary	B	5.7	124 Fatty	E	7.4	175 Caudate nucleus	C, L ⁹	1.36	Sheep		
18 Cerebral cortex	I	13.6	73 Pancreas	C	3.7	125 Lung	B	6.1	176 Cerebellum	C, L ⁹	1.07	226 Brain cortex	D ¹	19.7
19 Cerebral cortex	J	9.5	74 Pancreas	B	5.2	126 Lung	C	7.4	177 Cerebral cortex	C, L ⁹	1.16	227 Kidney cortex	D ¹	27.5
20 5 da	B	6.2	75 Pituitary, anterior	B	5.9	127 Lung	D ¹	8.5	178 Cerebral cortex	B	6.7	228 Liver	B	2.5
21 50 da	B	14.7	76 Posterior	B	6.6	128 Muscle, smooth ⁹	B	1.7	179 Heart	M	2.6	229 Liver	D ¹	8.5
22 Adult	B	8.5-17.1	77 Young	A	12.0	129 Of castrate	B	1.4	180 Heart	L	2.7	230 Lung	D ¹	5.4
23 Chorion	B	13.5	78 Placenta	F	3.9	130 Pancreas	C	2.7	181 Heart	I	4.6	231 Sperm, ejaculated	D	9.0
24 Diaphragm	M	6.3 ²	79 20 da	E	7.3	131 Salivary gland	C	5.0	182 Heart	K	6.3	232 Spleen	D ¹	6.9
25 Diaphragm	L	5.4	80 Prostate	B	7.6	132 Skin	B	3.0	183 Kidney cortex	D ¹	27.0	233 Trigeminal, nerve	E	0.5
26 Diaphragm	I	9.4 ³	81 Retina	B	22.0-32	133 Sperm	D	8.0	184 Liver	D ¹	6.0	234 Ganglion	E	0.3
27 Diaphragm	K	6.3 ⁴	82 Salivary gland	B	11.6-16.6	134 Sperm	A	18.4	185 Liver	D ¹	11.7	Chick		
28 Embryo, 1-3 mg	A	10.5-14.6	83 Skin, newborn	B	3.5	135 Spleen	D ¹	11.6	186 Lung	C, L ⁹	4.9	235 Allantois	B	22.3
29 13-14 da	B	7.2-11.0	84 10-36 da	B	4.9-3.6 ⁸	136 Spleen	C	8.13	187 Medulla	D ¹	0.69	236 Embryo, 0.1-1.2 g	A	15.9-21.4
30 Ganglion, dorsal root	E	8.0	85 79 da, adult	B	1.8-1.2 ⁸	Rabbit			188 Muscle, skeletal	D ¹	1.2	237 4.7 g	A	8.1
31 Hypothalamus	B	10.4	86 Sperm	A	7.7	137 Brain cortex	D ¹	28.2	189 Muscle, skeletal	L	1.3	238 5-6 da	E	10-12
32 Kidney	M	15.8 ⁵	87 Spleen	D ¹	12.7	138 Cerebral cortex	B	7.3-10.4	190 Muscle, skeletal	I	1.7	239 12 da	E	9.9
33 Kidney	N	38.0	88 Spleen	B	7.2-12.9	139 Embryo	B	8.5	191 Diaphragm, young	B	1.9	240 19 da	E	7.7
34 Kidney	O	23.2	89 Spleen	A	13.0	140 Ganglion, celiac	A	4.0	192 Diaphragm, juvenile	B	4.2	241 Brain	A	25.0
35 Kidney	L	23.1 ⁶	90 Testis	B	7.2-14.3	141 Kidney cortex	D ¹	34.5	193 Heart	B	2.6	242 Heart, 4 da	A	30
36 Kidney	I	34.0	91 Testis	B	11.6	142 Liver	D ¹	11.6	194 Pancreas	B	3.2	243 Heart, 6-7 da	A	14.9
37 Kidney	K	26.0	92 Thymus	A	11.0	143 Liver	B	4.2-7.7	195 Retina	B	20.8	244 Liver, 6 da	B	7.5
38 Kidney cortex	D ¹	38.2	93 Thyroid	B	5.5-5.8	144 Lung	D ¹	8.0	196 Salivary	B	10.6	245 Liver, 12 da	B	4.5
39 Liver	M	7.2 ⁷	94 Uterus	B	12.5-13	145 Lung	B	6.7	197 Spinal cord	C, L ⁹	0.5	246 Liver, 20 da	B	1.5
40 Liver	O	8.1	95 Uterus	B	7.6	146 Marrow, erythroid cells	A	9.0	198 Spleen	D ¹	6.6	Fowl		
41 Liver	L	9.0	96 Castrate	E	3.7	147 Myeloid cells	A	6.0	199 Thalamus	C, L ⁹	1.01	247 Liver, hen	A	14.5
42 Liver	I	10.7	97 Castrate, plus estrogen	E	5.2	148 Mucosa, colon	B, A	11.1	200 Thyroid	A	9.1	248 Sperm, ejaculated	D	2.8
43 Liver	J	26.0	Mouse			149 Uterine	A	6.1	201 Thyroid	B	2.0	Pigeon		
44 Liver	D ¹	17.2	98 Adrenal	A	6.0	150 Muscle, diaphragm	B	2.4	202 Midbrain	C, L ⁹	0.92	249 Cerebral cortex	C, L ⁹	14.6
45 Liver, fetus	A, B	7.1	99 Brain cortex	D ¹	32.9	151 Smooth, intest.	B	2.6	Horse			250 Lung	B	3.6
46 3-21 da	B	13.2	100 Cerebral cortex	E	11.0	152 Pancreas	B	4.6	203 Brain cortex	D ¹	15.7	251 Muscle, skeletal	C	2.1
47 Adult	E	9.8-10.2	101 Embryo	B	10.4	153 Placenta, fetal side	A	5.3	204 Kidney cortex	D ¹	21.5	252 Pancreas	C	8.7
48 Adult	B	6.5-11.6	102 Kidney cortex	D ¹	46.1	154 Uterine side	A	3.4	205 Liver	D ¹	5.4	Frog		
49 Lung	D ¹	8.6	103 Liver	B	8.8-13.8	155 Sperm, ejaculated	D	4.4	206 Liver	B	2.1	253 Hippocampus	E	2.4
50 Adult	C	7.9	104 Liver	E	18.7	156 Spleen	D ¹	14.2	207 Lung	D ¹	4.4	254 Muscle, skel., rest.	B	18-24
51 Adult	B	4.4-7.8	105 Liver	D ¹	23.1	157 Testis	B	7.7	208 Spleen	D ¹	4.2	255 Elect. stim.	E	79-4.24
52 Embryo	A	10.0	106 Lung	B	7.3-8.0	158 Thyroid	B, A	11.7	Cattle			256 Smooth, intest.	B	28
53 Lymph nodes	B	4.4	107 Lung	D ¹	12.0	159 Brain cortex	D ¹	26.9	209 Brain cortex	D ¹	17.2	257 Nerve, sciatic	E	0.3
54 Mammary, term. of preg.	B	1.3							210 Kidney cortex	D ¹	23.5	258 Retina	B	3.5
												259 Spinal cord	B	2.3

/1/ Medium essentially Ca-free Ringer phosphate, but containing pyruvate (or lactate), fumarate, glutamate and glucose. /2/ Value of 5.4 also reported. /3/ Value of 8.1 also reported. /4/ Value of 9.8 also reported. /5/ Value of 17.8 also reported. /6/ Value of 19.4 also reported. /7/ Value of 8.8 also reported. /8/ Range shows a decrease with age. /9/ Phosphate saline medium containing glucose. /10/ From seminal vesicles.

242. RESPIRATION RATES. ANIMALS

Data unless otherwise specified are for adults in resting or basal state. Rate values for protozoa are cubic millimeters oxygen per million cells per hour, and for metazoa, cubic millimeters oxygen per gram fresh weight per hour (= cubic centimeters per kilogram per hour). Rates for poikilothermic vertebrates and invertebrates were measured at the indicated ambient temperatures.

Organism	Rate	Organism	Rate	Organism	Rate
Mammalia		Amphibia		Annelida (concluded)	
1 Man, maximum work	4000	80 Molge vulgaris, 20°C	123	153 Nereis virens, 15°C	26
2 Man, resting	200	81 Rana esculenta, winter, 20°C	85	154 Sipunculus nudus, 16°C	50
3 Anteater, spiny	1100	82 R. esculenta, summer, 20°C	437	155 Tubifex sp, 15°C	200
4 Armadillo	201	83 R. fusca, winter, 20°C	100	Mollusca	
5 Bat, brown, big	800	84 R. fusca, summer, 20°C	210	156 Aplysia limacina, 16°C	30
6 Bat, brown, little	1500	85 R. temporaria, winter, 19°C	85	157 Eleodone moschata, 16°C	181
7 Bear, polar, cub	700	86 R. temporaria, summer, 19°C	554	158 Helix pomatia, 20°C	94
8 Cat, Australian, native	560	Pisces		159 Limax agrestis, 20°C	350
9 Cow	390	87 Anguilla vulgaris, 25°C	128	160 Mytilus edulis, 14°C	13
10 Dog	580	88 Arapaima gigas, 25°C	9	161 M. galloprovincialis, 25°C	18
11 Dormouse, awake	852	89 Cobitis fossilis, 20°C	51	162 Octopus vulgaris, 16°C	47-87
12 Dormouse, hibernating	15	90 Crenichthys baileyi, 37°C	546	163 Pleurobranchia meckelli, 25°C	36
13 Elephant, Indian, 37 yr, ♀	155	91 Cyprinus tinca, 20°C	104	164 Pterotrachea coronata, 16°C	7.8
14 Fox, arctic, white	505	92 Esox lucius, 18°C	102	165 Sepia officinalis, 15°C	320
15 Guinea pig	1250	93 Heliasis chromis, 20°C	162	166 Tethys leporina, 16°C	12
16 Hamster	1050	94 Lepidosiren paradoxa, 20°C	42	Echinodermata	
17 Hamster, golden, awake	2900	95 Salmo trutta, 12°C	226	167 Asterias rubens, 15°C	30
18 Hamster, golden, hibernating	70	96 Scomber scombrus, 20°C	726	168 Holothuria impatiens, 25°C	17
19 Horse	130	97 Serranus scriba, 20°C	151	169 Ophioderma longicauda, 25°C	8-32
20 Lemming	1700	98 Sphoeroides maculatus, 20°C	62	170 Strongylocentrotus lividus, 25°C	15
21 Manatee, Florida sea cow	120	99 Stenotomus chrysops, 20°C	174	Nemathelminthes	
22 Marmoset	1040	100 Tautoga onitis, 20°C	62	171 Ascaridia galli, 37°C	525
23 Monkey, night	510	101 Tautogolabrus adspersus, 21°C	120	172 Ascaris lumbricoides, large, 37°C	72
24 Mouse, house, basal	1530	Cephalochordata and Tunicata		173 A. lumbricoides, small, 37°C	156
25 Mouse, house, resting	3500	102 Amphioxus lanceolatus, 16°C	35	174 A. lumbricoides, ♂, 37°C	112
26 Opossum, Australian	700	103 A. lanceolatus, 20°C	45	175 A. lumbricoides, ♀, 37°C	61
27 Platypus, duckbilled	460	104 Ascidia mentula, 25°C	4.8	176 Heterakis spumosa, 38°C	880
28 Porpoise	360	105 Salpa pinnata, 16°C	8	177 Litomosoides carinii, 37.5°C	800
29 Rabbit	460-850	106 S. pinnata, 20°C	12	178 Nematodirus sp, 37°C	1070
30 Raccoon	395	107 S. tilesii, 16°C	2.0	179 Neaplectana glaseri, 30°C	2600
31 Rat	2000	108 S. tilesii, 20°C	2.8	180 Nippostrongylus muris, 37°C	1430
32 Rat, kangaroo	950	Arthropoda		181 Ostertagia circumcincta, 38°C	1480
33 Seal	540	109 Apis mellifera, resting, 20°C	17,466	182 Setaria equinum, 38°C	250
34 Sheep	340	110 A. mellifera, true flight, 20°C	87,000	183 Strongylus equinus, 38°C	511
35 Shrew, Monterey	7200	111 Asellus aquaticus, 17°C	348	184 Syphacia obvelata, 38°C	1010
36 Shrew, long-tailed	13,700	112 Astacus leptodactylus, 20°C	70	Platyhelminthes	
37 Shrew, short-tailed	5200	113 Callinax subterranea, 15°C	930	185 Dendrocoelum lacteum, 2.5°C	4.4
38 Shrew, Sonoma, ♂	6100	114 Carcinus maenas, 15°C	625	186 D. lacteum, 25°C	26.3
39 Shrew, Sonoma, ♀	5500	115 Cryptocercus punctulatus, 50°C	28.5	187 Diphylobothrium latum ² , 37°C	243
40 Sloth, two-toed	216	116 Culex sp, 20°C	575	188 Fasciola hepatica, 37.5°C	330
41 Sloth, three-toed	168	117 Drosophila americana, resting, 20°C	1560	189 Paramphistomum cervi, 38°C	3
42 Squirrel, arctic, ground	600	118 D. americana, true flight, 20°C	21,800	190 Planaria torva, 2.5°C	18.9
43 Squirrel, flying	2000	119 D. americana, true flight, 20°C	112	191 P. torva, 25°C	75.8
44 Swine	220	120 Emerita talpoida, 20°C	1828	192 Ttaenophorus nodulosus ³ , 22°C	418
45 Weasel	5000	121 Eriphia spinifrons, 15°C	532	Ctenophora	
46 Woodchuck, awake	262	122 Formica sp, 20°C	447	193 Beroe ovata, 16°C	5
47 Woodchuck, hibernating	14	123 Geotrupes sp, 21°C	507	194 Cestus veneris, 16°C	2.6
Aves		124 Homarus americanus, 15°C	253	195 C. veneris, 25°C	25
48 Bunting, snow	3350	125 Iliia nucleus, 15°C	500	Coelenterata	
49 Canary	2900	126 Limnophilus vittatus, 10°C	95,600	196 Anemonia sulcata, 18°C	13.4
50 Dove	950	127 Lucilia sericata ¹ , 20°C	1460	197 Aurelia aurita, 13°C	3.4
51 Duck	800	128 Maja verrucosa, 15°C	2400	198 Carmarina hastata, 16°C	6
52 Fowl, hen	630	129 Melanotus communis, 27°C	724-960	199 Rhizostoma pulmo, 16°C	7.2
53 Goose	547-592	130 Melolontha sp, 20°C	3200-5112	Porifera	
54 Gull, arctic	1640	131 Musca sp, 20°C	139	200 Suberites massa, 22.4°C	0.0241
55 Hawk, night	1750	132 Ocyrops albicans, 26°C	1600	Protozoa	
56 Hummingbird, day	13	133 Paguristis maculata, 15°C	128	201 Amoeba chaos chaos, 20°C	7050
57 Manakin	4620	134 Palaemon squilla, 19°C	12,874	202 A. chaos chaos, 25°C	9010
58 Pigeon	710	135 Palinurus vulgaris, 15°C	20	203 A. chaos chaos, 30°C	13,244
59 Sparrow	2100	136 Pandalina brevirostris, 15°C	30	204 Astasia klebsii, young, 25.2°C	3.8
Reptilia		137 Passalus cornutus, 17°C	277	205 Chilomonas paramecium, 25°C	16.4
60 Alligator lucius, 25°C	64	138 Periplaneta orientalis, 20°C	160	206 Leishmania braziliensis, 32°C	0.32
61 A. mississippiensis, 22°C	8.9	139 Pilumnus hirtellus, 15°C	100	207 Leptomonas ctenocephali, 28°C	0.27
62 Coluber natrix, 20°C	92-150	140 Pugettia producta, 15°C	443	208 Paramecium aurelia ⁴ , 20°C	354
63 Constrictor constrictor, 16°C	4.9	141 Sicyonia sculpa, 15°C	6	209 P. aurelia ⁴ , 25°C	616
64 C. constrictor, 22°C	10	142 Spirontocaris cranchi, 15°C	180	210 P. aurelia ⁴ , 35°C	1512
65 C. constrictor, 30°C	24	143 Talorchestia megalopthalma, 17°C	600	211 P. caudatum ⁴ , 20°C	2110
66 Crotalus atrox, 16°C	6.8	144 Venessa sp, resting, 20°C	100,000	212 P. caudatum ⁴ , 25°C	3860
67 C. atrox, 22°C	16.4	145 Venessa sp, true flight, 20°C	400	213 P. multimicronucleatum ⁵ , 25°C	1021
68 C. atrox, 30°C	35.5	146 Zootheropsis angusticollis, 20°C	30	214 Plasmodium cathemerium, 38°C	0.25
69 Drymarchon corais couperi, 16°C	10.1	Annelida		215 P. knowlesi, 38°C	0.34
70 D. corais couperi, 22°C	20	147 Arenicola sp, 12°C	8	216 Strigomonas fasciculata, 28°C	0.37
71 D. corais couperi, 30°C	47	148 Chaetopterus pergamentaceus, 15°C	15	217 Tetrahymena geleii ⁶ , 26.8°C	632.5
72 Iguana tuberculata, 22°C	22.2	149 Glycera siphonostoma, 25°C	206	218 Trichomonas foetus, 28°C	2.15
73 I. tuberculata, 30°C	52	150 Lumbricus communis, 21.5°C	45	219 Trypanosoma congolense, 37°C	1.53
74 Lacerta agilis, 20°C	1980	151 L. herculeus, 10°C	138	220 T. cruzi, 37°C	1.24
75 Malaclemys centrata, 24°C	35	152 L. terrestris, 20.5°C	138	221 T. gambiense, 37°C	1.70
76 Python reticulatum, 22°C	12.2			222 T. lewisi, old, 37°C	0.51
77 Storeria dekayi, ♂, 20°C	266			223 T. rhodesiense, 37°C	1.94
78 S. dekayi, ♀, 20°C	183				
79 Testudo vicina, 22°C	22				

/1/ True flight. /2/ Proglottids. /3/ Strobilia. /4/ No substrate. /5/ Bacteria present. /6/ Substrate present.

243. RESPIRATION RATES: PLANTS

Part I: FUNGI

Values for rates of gaseous exchange are $\mu\text{l}/\text{mg}$ dry weight/hour, except as otherwise specified. Data for aerobic CO_2 production are enclosed in parentheses; those for anaerobic CO_2 production in brackets. Values not enclosed are O_2 consumption.

Species	Material	Temp °C	Substrate	Specifications	$[\text{QCO}_2]$ or QO_2	RQ
Myxomycetes						
1 <i>Physarum polycephalum</i>	Plasmodium	22		Endogenous	(1.0) 2.4 ¹	0.75-0.85
Phycomycetes						
2 <i>Allomyces arbuscula</i>	Mycelial mat	20	Carbohydrate	Starved	0.8	
3 <i>A. moniliformis</i>	Mycelial mat		Carbohydrate	Starved	1.0	
4 <i>Cystopus candidus</i>	Mycelial mat		Natural	Host, host + fungus		0.93, 0.95
5 <i>Leptomitium lacteus</i>	Pellets	20		Endogenous; at 0, 4, 8 days	20, 15, 10	0.98
6 <i>Mucor guilliermondii</i>	Mycelial mat	25		Endogenous; mycelial phase	5.7-10 [7.1]	
7	Mycelial mat	25	Carbohydrate	+ Glucose; mycelial phase	5.6-21.4 [18.82]	
8	Mycelial mat	25		Endogenous; yeast phase	7.1-8.6	
9	Mycelial mat	25	Carbohydrate	+ Glucose; yeast phase	7.8-39 [31-142]	
10 <i>M. stolonifer</i>	Mycelial mat	20, 30	Carbohydrate			1.53, 1.72
11 <i>Phycomyces blakesleeana</i>	Mycelial mat	20	Carbohydrate	At 1.5, 3.5, 7 days	(27, 13, 3)	
12 <i>Rhizopus</i> sp	Mycelial mat	28	Carbohydrate		(4.7)	
Ascomycetes						
13 <i>Ashbya gossypii</i>	Mycelium ²	30		Endogenous; at 1, 2, 3 days	19, 11, 8	
14	Mycelium ²	30	Carbohydrate	+ Glucose; at 1, 2, 3 days	32, 20, 12	
15	Mycelium ²	30	Carbohydrate	+ Sucrose; at 1, 2, 3 days	30, 17, 13	
16	Mycelium ²	30	Carbohydrate	+ Lactose; at 1, 2, 3 days	0, 0, 0	
17	Mycelium ²	30	Complex	+ Pyruvate; at 1, 2, 3 days	8, 3, 0	
18	Mycelium ²	30	Complex	+ Ethanol; at 1, 2, 3 days	12, 8, 3	
19 <i>Erysiphe graminis tritici</i>	Growing culture	22	Natural	Host, host + fungus	1.7, 6.0 ³	
20 <i>Melanospora destruens</i>	Mycelial mat	30	Carbohydrate	+ Glucose	6	
21 <i>Neurospora crassa</i>	Mycelial mat	30	Organic comp'd	Endogenous	11-38 [0-5]	
22 <i>N. tetrasperma</i>	Sexual spores	25		Endogenous; dormant	0.2-0.6 [0.03]	
23	Sexual spores	25		Endogenous; germinating	9-22 [1-2]	
24 <i>Saccharomyces cerevisiae</i> R	Cell suspension		Carbohydrate	No stored reserves	83-109 [278-299]	
25	Cell suspension			Fat as reserves	76 [322]	
26	Cell suspension			Glycogen as reserves	0 [116]	
27 <i>S. cerevisiae</i> U	Cell suspension		Carbohydrate	No stored reserves	10-137 [276-284]	
28	Cell suspension			Fat as reserves	125 [261]	
29	Cell suspension			Glycogen as reserves	47 [83]	
30 <i>Sclerotinia</i> sp	Pellets	23-25	Carbohydrate			1.15
31 <i>Zygosaccharomyces acidifaciens</i>	Mycelium ²	28		Endogenous; at 24, 48, 72 hr	16, 7, 7	
32	Mycelium ²	28	Carbohydrate	+ Glucose; at 24, 48, 72 hr	60, 35, 35	
Basidiomycetes						
33 <i>Boletus luridus</i>	Sporophore	17		Endogenous	(1.5)	
34 <i>Bovista tunicata</i>	Sporophore			Endogenous	(1.8-1.1) [8.7-5.6]	
35 <i>Coprinus comatus</i>	Sporophore	17		Endogenous	(2.7)	
36 <i>Exidia glandulosa</i>						0.7
37 <i>Lactarius serifulus</i>	Sporophore	17		Endogenous	(2.7)	
38 <i>Polyporus squamosus</i>	Sporophore	17		Endogenous	(1.0)	
39 <i>Polystictus versicolor</i>	Mycelial mat	17.5	Complex	At 2, 21, 100% O_2	3, 4.5, 10.4 ³	
40	Mycelial mat	29.5	Complex	At 2, 21, 100% O_2	7.4, 4.2, 17.2 ³	
41 <i>Psalliota campestris</i>	Growing culture	25			1.9-2.9	
42 <i>Puccinia pruni</i>	Growing culture		Natural	Host, host + fungus		1.06, 0.82
43 <i>Ustilago sphaerogena</i>	Conidia			Endogenous	75	
44	Conidia		Carbohydrate	+ Sugars	150-375	
Fungi Imperfecti						
45 <i>Aspergillus clavatus</i>	Mycelial mat	15-25	Carbohydrate		12.4	
46	Mycelial mat		Complex		44	
47 <i>A. flavus</i>	Mycelial mat	30	Carbohydrate	At 4-6 days	6-7	
48 <i>A. niger</i>	Mycelial mat	19, 35	Carbohydrate	+ Glucose		0.98, 1.30
49	Mycelial mat	18, 35	Carbohydrate	+ Sucrose		0.91, 1.22
50	Mycelial mat	36	Carbohydrate	+ Glycerol		0.82-0.86
51	Mycelial mat	35	Carbohydrate	+ Mannitol		1.20
52 <i>Blastomyces dermatitidis</i>	Cell suspension	37		Endogenous; at pH 2, 6, 8	0.5, 12, 11 ⁴	
53	Cell suspension	37	Carbohydrate	+ Glucose; at pH 2, 6, 8	1, 12, 12 ⁴	
54 <i>Candida albicans</i>	Cell suspension	30		Endogenous	5	
55	Cell suspension	30	Carbohydrate	+ Glucose	40	
56 <i>Fusarium avenaceum</i>	Pellets	23-25	Natural			5.46
57 <i>F. dianthi</i>	Pellets	23-25	Natural			1.85
58 <i>F. trichothecioides</i>	Mycelium ²	30		Endogenous; at 1-4 hrs ⁵	31-11	
59	Mycelium ²	30	Carbohydrate	+ Glucose; at 1-4 hr ⁵	64-56	
60 <i>Helminthosporium gramineum</i>	Pellets	23-25		Endogenous		1.31
61 <i>H. inaequalis</i>	Pellets	23-25		Endogenous		1.16
62 <i>Memnoniella echinata</i>	Conidia	30		Endogenous; at pH 4, 6, 8	1.0, 1.5, 1.3	
63	Conidia		Carbohydrate	+ Glucose; at pH 4, 6, 8	2.6, 3.1, 2.7	
64	Conidia		Carbohydrate	+ Lactose; at pH 4, 6, 8	0.7, 1.3, 1.2	
65 <i>Myrothecium verrucaria</i>	Conidia	30	Carbohydrate	+ Glucose; at pH 4, 6, 8	19, 25, 30	
66	Conidia		Carbohydrate	Endogenous; at pH 4, 6, 8	2.9, 2.6, 5.6	
67	Pellets			Starved, sucrose grown	42	
68 <i>Penicillium chrysogenum</i>	Pellets	23-25	Carbohydrate	3 strains		1.10-1.27
69 <i>P. digitatum</i>	Pellets	23-25	Carbohydrate	4 strains		1.39-1.63
70 <i>P. notatum</i>	Mycelial mat	23-25	Carbohydrate	At 4-8-11 days	46-198-152 ⁴	
71 <i>Torulopsis utilis</i>	Cell suspension	30		Glycine	3.7 ¹	0.86
72	Cell suspension	30		Urea	3.5 ¹	1.15
73	Cell suspension	30		α -Alanine	5.2 ¹	0.89
74	Cell suspension	30		β -Alanine	4.2 ¹	1.16

/1/ $\mu\text{l}/\text{mg}$ wet wt/hr. /2/ Homogenized. /3/ $\mu\text{l}/\text{sq cm}$ area/hr. /4/ $\mu\text{l}/10 \mu\text{l}$ tissue volume/hr. /5/ 1-day old.

243. RESPIRATION RATES: PLANTS (Continued)

Part II: BACTERIA

Data are applicable to bacterial suspensions in the presence of glucose.
Values are ml/mg dry weight/hr.

Species	Temp °C	Culture Age hr	QO ₂
1 Azotobacter chroococcum	22	36	2,000-10,000
2 Aerobacter aerogenes	36, 30	17, 48	47, 50
3 Bacillus cereus (short)	30?	18	42-86
4 B. cereus (filamentous)	30?	18	3-49
5 B. subtilis	37	6-8	170
6 Escherichia coli	40, 32	20	200, 272
7 Lactobacillus bulgaricus	37, 45	8	34, 55
8 Leuconostoc citrovorum	38	16	8
9 Micrococcus luteus	35	30-34	15
10 M. flavus	35	30-34	8
11 M. auranticus	35	30-34	14
12 M. cinereus	35	30-34	32
13 M. freudenreichii	35	30-34	20
14 Mycobacterium phlei	38	84	28
15 M. smegmatis	38	84	23
16 M. stercois	38	84	15
17 M. sp. Karlinski	38	84	22
18 M. ranee	38	84	32
19 M. leprous kedrowsky	38	84	8
20 M. butyricum	38	84	13
21 M. tuberculosis hominis	38	252	4
22 M. tuberculosis avian	37	84	1
23 Pneumococcus, Type I	37	18	27
24 Pseudomonas fluorescens	26	20	58
25 Streptococcus faecalis, B33A	38	18	106
26 S. faecalis, 10C1	37	15	57-80
27 S. faecalis, Lancefield D	37	12-15	7
28 S. thermophilus, C3	37, 50	8	4, 5
29 S. thermophilus, MC	37, 50	8	9, 10

Part III: ALGAE

Values for rates of gaseous exchange are $\mu\text{l}/100 \text{ mg dry weight/hr.}$, except as otherwise specified. Data for O₂ consumption are enclosed in brackets; those for aerobic CO₂ are not enclosed; those for CO₂ production are not enclosed.

Species	Temp °C	QCO ₂ or [QO ₂]	RQ
Cyanophyta (Blue Green)			
1 Anabaena sp	25	414	0.90
2 Nostoc commune	19	0.16	0.40
Chlorophyta (Green)			
3 Chara vulgaris	18	1.5 ¹	
4 Chlorella ellipsoidea	25	[147]	
5 C. pyrenoides	20	89	0.89
6 C. vulgaris	20	[475-192] ²	
7 Cladophora rupestris	20	[33]	
8 Coelastrum proboscideum	20	[170]	
9 Enteromorpha compressa	20	27	3.6
10 E. linza	19	66	0.62
11 Haematococcus pluvialis	20	[180]	
12 Nitella flexilis	18	1.6	
13 Scenedesmus obliquus	25	[50]	
14 Spirogyra majuscula	10.4	[0.5] ¹	
15 S. varians	10.4	[0.6] ¹	
16 Ulva lactuca	20	13-16	2.4-6.1
17 Valonia utricularis	20	8.4	1.5-5.7
Phaeophyta (Brown)			
18 Ascophyllum nodosum	20	1.6 ¹	0.80
19 Chorda tomentosa	9	[74]	
20 Cutleria multifida	20	7.2-17	0.5-2.1
21 Cystoseira abrotanifolia	20	4.5-10	1.2-3.7
22 C. amentacea	20	17	3.9
23 C. barbata	20	13-17	2.1-4.0
24 Desmarestia aculeata	14	[24]	
25 D. viridis	14	[14] ¹	
26 Dictyota dichotoma	20	9.4-9.2	0.98-1.04
27 Ectocarpus siliculosus	12	[41] ¹	
28 Fucus serratus	18	18 ¹	0.54
29 F. vesiculosus	17	11	0.60
30 Laminaria digitata	17	[2] ¹	
31 Taonia atomaria	20	6.7-20	0.9-3.1
Rhodophyta (Red)			
32 Ceramium rubrum	17	45	0.89
33 Chondrus crispus	14	[18]	
34 C. crispus	20	[28]	
35 Cladostephus spongiosus	20	[39]	
36 Cryptonemia lomatium	20	7.5-9.9	2.4-3.8
37 Delesseria alata	20	[41]	
38 Furcellaria fastigiata	14	[7]	
39 Gelidium corneum	20	13	3.26
40 Gracilaria compressa	20	9	1.4
41 Laurencia papillosa	20	18	4.88
42 Phyllophora nervosa	20	4.6	1.56
43 Plocamium coccineum	14	[21]	
44 Polydora lumbricoides	14	[5]	
45 Polysiphonia urceolata	12	[10] ¹	
46 P. violacea	11	107	1.02
47 Porphyra laciniata	17	[39]	

/1/ $\mu\text{l}/100 \text{ mg fresh wt/hr.}$ /2/ $\mu\text{l}/10^9 \text{ cells/hr.}$

Part IV: LICHENS

Values are $\mu\text{l}/100 \text{ mg dry weight/hr.}$

Species	Temp °C	QO ₂	RQ
1 Alectoria nigricans	33	14	8
2 Cetraria chrysanthra	19	9	3.9
3 C. glauca	61	31	10
4 C. islandica	48	19	8
5 Cladonia scholanderi	13	7.5	3.1
6 C. sylvatica	24	6.8	2.9
7 Cornicularia divergens	40	11	5
8 Lobaria linita	72	22	10
9 L. scrobiculata	50	29	12
10 Parmelia nigroclivata	25	13	4
11 Peltigera aphthosa	90	33	17
12 Ramalina alludens	13	3.3	2.2
13 Solorina crocea	43	24	10
14 Sticta laciniata	28	11	7
15 S. weigelii	40	14	6.7
16 Thamnolia vermicularis	28	14	4.2
17 Umbilicaria cinereorufescens	30	9.8	4.1
18 U. proboscidea	18	6.5	3.5
Liverworts (Hepaticae)			
19 Cladonia rangiferina	50	10	0.80
20 Evernia prunastri	50	40	0.78
21	60	30	0.88
22 Orthotrichum affine	55	17	0.70
23 Pertusaria communis			0.84
24 Physcia aipolia			0.73
25 F. ciliaris	45	18	0.80
26 Ramalina farinacea	50	25	0.77

Part V: LIVERWORTS, MOSSES

Values are $\mu\text{l}/100 \text{ mg dry weight/hr.}$, except as otherwise specified. Data for O₂ consumption are enclosed in brackets; those for aerobic CO₂ are not enclosed.

Species	Temp °C	QCO ₂ or [QO ₂]	RQ
Liverworts (Hepaticae)			
1 Chiloscaphus fragilis	25	[60-100]	
2 Marchantia polymorpha	20	0.6 ¹	
3 Riccia fluitans	25	[250-300]	
Mosses (Musci)			
4 Fontinalis antipyretica	25	[70-140]	
5 Hylocomium parietinum	30	92	
6	20	46	
7	0	15	
8 H. proliferum	30	92	
9	20	46	
10	0	15	
11 H. squarrosum	30	100	
12	20	61	
13	0	15	
14 Hypnum cupressiforme	18.5	[2-30]	
15 H. fluitans	18	0.83 ²	
16 Polytrichum juniperium, shoot ³	18	1.2-0.7 ²	
17 Sphagnum girgensohnii	30	130	
18	20	71	
19	5	20	

/1/ $\mu\text{l}/\text{sq cm/hr.}$ /2/ $\mu\text{l}/100 \text{ mg fresh wt/hr.}$ /3/ Data show changes during growth, development, maturation.

Part VI: HORSETAILS, FERNS

Values for gaseous exchange are $\mu\text{l}/100 \text{ mg wet weight/hr.}$ Data for O₂ consumption are enclosed in brackets; those for aerobic CO₂ production are not enclosed.

Species	Material	Temp °C	QCO ₂ or [QO ₂]	RQ
Horsetail (Equisetaceae)				
1 Equisetum maximum	Shoot	20	6	0.78
2	Fruiting shoot	20	100	0.83
3	Stem	RT	9.6	0.80
4	Branchlet	RT	19	0.69
Ferns (Filicinae)				
5 Asplenium adiantum nigrum	Leaf	20	13	0.86
6	Leaf with sori	20	17	1.01
7	Leaf blade	RT	13.4	0.80
8	Petiole	RT	8.3	0.80
9 Dryopteris austriaca	Leaf	48	122	
10	Leaf	30	36	
11	Leaf	10	25	
12 Eupteris aquilina	Leaf	48	168	
13	Leaf	30	46	
14	Leaf	10	15	
15 Polypodium virginiana	Leaf	20	10	0.92
16	Leaf with sori	20	19	1.06
17 Pteris aquilina	Leaf	22	19	0.84
18	Leaf with sori	22	35	1.01
19 Scolopendrium scolopendrium	Leaf	30	[31]	
20	Leaf	22	[17.5]	
21	Leaf	13	[9.9]	
22	Leaf	3	[2.2]	

243. RESPIRATION RATES: PLANTS (Continued)

Parts VII, VIII, IX, and X

Values for rates of gaseous exchange are $\mu\text{l}/100\text{ mg wet weight}/\text{hour}$, except as otherwise specified. Data for anaerobic CO_2 production are enclosed in parentheses; those for O_2 consumption in brackets. Values not enclosed are aerobic CO_2 production.

Part VII: SEEDS AND PARTS

Species	Material ¹	Temp °C	QCO_2	RQ
1 Apple (<i>Pyrus malus</i>)	Resting	19	2.8 ²	0.86
2 Alfalfa (<i>Medicago sativa</i>)	Resting	18	41	1.08
3	Germinating	18	91	0.86
4 Barley (<i>Hordeum vulgare</i>)	Resting		8.7	
5	Embryo		63	
6	Endosperm		3.6	
7 Bean (<i>Phaseolus coccineus</i>)	Resting	28		1.75
8 Broadbean (<i>Vicia faba</i>)	Resting	28		0.99
9 Broom (<i>Cytisus laburnum</i>)	Resting	28		1.16
10 Buckwheat (<i>Fagopyrum esculentum</i>)	Germinating	25	41-306	0.8-1.0
11 Castor bean (<i>Ricinus communis</i>)	Resting	28		1.03
12	Endosperm	30	54	0.38
13 Cherry (<i>Prunus cerasus</i>)	Moist	25	5.6	0.87
14 Coconut (<i>Cocos nucifera</i>)	Moist	30	100-200	
15	Endosperm	30	0	
16	Hypocotyl	30	50	
17 Corn (<i>Zea mays</i>)	Resting		1.7	
18	Embryo		22.6	
19	Endosperm		0.36	
Cotton (<i>Gossypium herbaceum</i>)				
20 Coker	Resting	26	0.1-1.5	0.92-1.05
21 Delfos	Resting	26	0.03-6.0	0.96-1.12
22 Flax (<i>Linum usitatissimum</i>)	Resting	17	21.8	0.91
23	Germinating	18	117	0.55
24 Hemp (<i>Cannabis sativa</i>)	Resting	18	9.0	0.82
25 Lamb's-quarters (<i>Chenopodium album</i>)	Moist	25	8.9	0.93
26 Peach (<i>Prunus persica</i>)	Moist	25	3.9	0.68
27 Plum (<i>P. domestica</i>)	Resting	28		0.80
28 Plum, blue gage (<i>P. domestica</i>)	Moist	25	5.6	0.70
29 Plum, Burbank (<i>P. domestica</i>)	Moist	25	4.3	0.91
30 Pumpkin (<i>Cucurbita pepo</i>)	Germinating	25	10-117	0.94-0.62
31 Radish (<i>Raphanus sativus</i>)	Resting	20	6.0	0.86
32	Germinating	20	60	0.58
33 Red cedar (<i>Juniperus virginiana</i>)	Resting	25	0.05	0.76
34	Germinating	25	6.6-25	0.84-0.97
35 Rice (<i>Oryza sativa</i>)	Resting		0.03 ²	1.15
36	Moist		5.5 ²	1.96
37	Germinating		9.7 ²	1.98
38	Seedling		1.1 ²	1.00
39 Rye (<i>Secale cereale</i>)	Resting	38	0.002-0.12	
40 Smartweed (<i>Polygonum scandens</i>)	Moist	6		0.90
41	Moist	30		0.92
42 Sorghum (<i>Sorghum vulgare</i>)	Resting	37.8	0.01-0.3 ²	
43 Sorrel (<i>Rumex crispus</i>)	Moist	25	7.8	1.16
44 Sunflower (<i>Helianthus annuus</i>)	Resting	28		1.05
45 Walnut (<i>Juglans regia</i>)	Resting	28		0.52
46 Watermelon (<i>Citrullus vulgaris</i>)	Resting	28		0.90
47 Wheat (<i>Triticum aestivum</i>)	Resting	65		0.3 ²
48	Resting	55		0.72
49	Resting	35		0.03 ²
50	Resting	4		0.005 ²

/1/ Condition of seeds: resting=dormant, air-dry; moist=with imbibed water. /2/ $\mu\text{l}/100\text{ mg dry wt}/\text{hr}$.

Part VIII: STEMS

Species	Temp °C	QCO_2 or $[\text{QO}_2]$	RQ
1 Apple, Jonathan (<i>Pyrus malus</i>) ²	6	2.3-4.6	
2 Apple, McIntosh (<i>P. malus</i>) ²	6	1.7-3.8	
3 Asparagus (<i>Asparagus officinalis</i>) ³	24	35-13.2	1.04-0.95
4	10	9.7-3.6	1.03-0.86
5	0.5	3.0-2.0	0.98-0.95
6 Borage (<i>Borago officinalis</i>)	RT	6.1	0.81
7 Broadbean (<i>Vicia faba</i>)	RT	6.2 (5.6)	
8 Broom (<i>Spartium junceum</i>)	RT	16	0.80
9 Charlock (<i>Raphanus raphanistrum</i>)	RT	10.5	0.87
10 Cinquefoil (<i>Potentilla reptans</i>)	RT	11.0	0.83
11 Clematis (<i>Clematis cirrhosa</i>)	RT	12.4 (7.5)	
12 Cotton (<i>Gossypium herbaceum</i>) ⁴	38	168-42 ⁵	
13 Elder (<i>Sambucus nigra</i>)	RT	9.8 (7.7)	
14 Nettle (<i>Urtica membranacea</i>)	RT	8.8	0.88
15 Oak (<i>Quercus coccifera</i>)	21	31-11	0.89-0.83
16 Oxalis (<i>Oxalis corniculata</i>) ⁴	RT	15.4	0.97
17 Pea (<i>Pisum sativum</i>)	RT	14.9	0.86
18 Smartweed (<i>Polygonum persicaria</i>)	RT	6.9	0.82
19 Sorrel (<i>Rumex lunaria</i>)	RT	10 (8.1)	
20 Sorrel (<i>R. pulcher</i>)	RT	11.8	0.85
21 Sugar cane (<i>Saccharum officinarum</i>) ⁴	28	27-4 ⁵	
22 Vetch (<i>Vicia sativa</i>)	RT	14.9	0.86

/1/ RT=room temperature. /2/ Tissue precooled. /3/ Material observed under conditions of storage or starvation. /4/ Data applicable to conditions of growth, development, maturation. /5/ $\mu\text{l}/100\text{ mg dry wt}/\text{hr}$.

Part IX: FLOWERS AND PARTS

Species	Material	Temp °C	QCO_2 or $[\text{QO}_2]$	RQ
1 Agave (<i>Agave attenuata</i>) ¹	Stamen	15	24-21	0.78-0.74
2	Pistil	14	34-13-11	0.92-0.69
3 Aloe (<i>Aloe arborescens</i>) ¹	Stamen	17	36-21-11	
4	Pistil	17	26-23-25	0.93-0.94
5 Arum (<i>Arum italicum</i>)	Spadix	18	[2800]	
6 Begonia (<i>Begonia rex</i>)	Sepal	20	39	
7	Petal	20	37	
8	Stamen	20	43	
9	Pistil	20	31	
10 Cactalia (<i>Cactalia verbascifolia</i>)	Flower	18	34(15)	
11 Canna (<i>Canna indica</i>)	Petal	22	27	0.79
12	Stamen	22	65	0.72
13	Pistil	22	45	0.78
14 Columbine (<i>Aquilegia vulgaris</i>)	Ovule	20	[190] ²	
15 Cucumber (<i>Cucumis sativus</i>) ¹	Pistil	22	48-43-29	
16 Cyclamen (<i>Cyclamen persicum</i>)	Flower	28		1.03
17 Dahlia (<i>Dahlia variabilis</i>)	Petal	28		0.94
18 Delphinium (<i>Delphinium sinense</i>)	Flower	28		0.94
19 Eel-grass (<i>Vallisneria spiralis</i>)	Flower	20	[30] ²	
20 Elder (<i>Sambucus nigra</i>)	Flower	28		0.95
21 Fleabane (<i>Erigeron annua</i>)	Flower	18	[40] (23)	
22 Gladiolus (<i>Gladiolus gandavensis</i>)	Petal	24	15	0.72
23	Stamen	24	27	0.77
24	Pistil	24	71	0.90
25 Lilac (<i>Syringa vulgaris</i>)	Flower	20	40	
26 Jasmine (<i>Jasminum nudiflorum</i>)	Flower	28		0.01
27 Lily (<i>Lilium elegans</i>)	Pollen	25	[610] (240) ²	
28 Lily (<i>L. hansonii</i>)	Pollen	25	[340] (260) ²	
29 Lily (<i>L. philippinensis</i>)	Pollen	25	[1140] (980) ²	1.04
30 Marsh marigold (<i>Caltha palustris</i>)	Ovule	20	[360] ²	
31 Mullein (<i>Verbascum thapsus</i>)	Stamen	23	76	0.83
32	Pistil	23	82	0.92
33 Peony (<i>Paeonia albiflora</i>)	Pollen	25	[700] (170) ²	
34 Pine (<i>Pinus densiflora</i>)	Pollen	25	[160] (150) ²	
35 Poppy (<i>Papaver orientale</i>)	Pollen	25	[520] (0) ²	
36 Poppy (<i>P. rhoeas</i>)	Sepal	21	39	
37	Petal	21	37	
38	Stamen	21	104	
39	Pistil	21	69	
40 Primrose (<i>Primula obconica</i>)	Flower	28		0.96
41 Sweetpea (<i>Lathyrus odoratus</i>)	Ovule	20	[420] ²	
42	Ovary	20	[300] ²	
43	Filament	20	[160] ²	
44 Tulip (<i>Tulipa genneriana</i>)	Flower	28		0.95

/1/ Data show changes during growth, development, maturation. /2/ $\mu\text{l}/100\text{ mg dry wt}/\text{hr}$.

Part X: STORAGE ORGANS

Species	Material	Temp °C	QCO_2 or $[\text{QO}_2]$	RQ
1 Arrow-head (<i>Sagittaria latifolia</i>)	Rhizome	25	4.1 (3.2)	
2 Artichoke (<i>Cynara scolymus</i>) ¹	Tuber	25	1.4-0.8 (0.5)	
3 Beet (<i>Beta vulgaris</i>)	Root	15.5	0.8	
4 Bur-reed (<i>Sparganium eurycarpum</i>)	Rhizome	25	[2.3] (1.6)	
5 Carrot (<i>Daucus carota</i>) ¹	Root	24	3.3-1.5	1.10-1.18
6		10	1.5-0.5	1.08-1.01
7		0.5	0.4-0.2	0.92-1.16
8 Cattail (<i>Typha latifolia</i>)	Rhizome	25	2.4(2.1)	
9 Dahlia (<i>Dahlia variabilis</i>)	Root	25		0.99
10 Gladiolus (<i>Gladiolus</i> sp)	Corn	23	8.5 ²	
11 Milkweed (<i>Asclepias incarnata</i>)	Rhizome	25	3.7(4.3)	
12 Onion (<i>Allium cepa</i>)	Bulb	21	0.7-1	
13		10	0.4-0.5	
14		0	0.1-0.2	
15 Oxalis (<i>Oxalis cernua</i>)	Rhizome	RT	5	1.18
16 Potato (<i>Solanum tuberosus</i>) ¹	Tuber	24	0.6-0.3	1.02-0.75
17		10	0.2-0.15	0.86-0.99
18		0.5	0.07-0.15	0.45-0.66
19 Sedge (<i>Scirpus validus</i>)	Rhizome	25	2.8(3.4)	
20 Sweetflag (<i>Acorus calamus</i>)	Rhizome	25	3.7(3.7)	
21 Sweetpotato (<i>Ipomoea batatas</i>)	Root	35	6.2	
22		25	4.0	
23		15	1.9	
24 Triumph	Root	35	5.6	
25		25	3.2	
26		15	1.4	
27 Turnip (<i>Brassica rapa</i>)	Root	15.5	1.6	
28		4.5	0.1	
29		0	0.02	
30 Waterlily (<i>Nuphar advenum</i>)	Rhizome	25	3.0(2.6)	

/1/ Material observed under conditions of storage or starvation. /2/ $\mu\text{l}/100\text{ mg dry wt}/\text{hr}$.

243. RESPIRATION RATES: PLANTS (Concluded)

Values for rates of gaseous exchange are $\mu\text{l}/100\text{ mg wet weight}/\text{hour}$, except as otherwise specified. Data for anaerobic CO_2 production are enclosed in parentheses; those for O_2 consumption in brackets. Values not enclosed are aerobic CO_2 production.

Part XI: LEAVES				Part XII: FRUITS			
Species	Temp ¹ °C	QCO_2 or $[\text{QO}_2]$	RQ	Species	Temp ¹ °C	QCO_2 or $[\text{QO}_2]$	RQ
1 Almond (<i>Prunus amygdalus</i>)	14	29	1.00	1 Apple (<i>Pyrus malus</i>)	20	1.7-0.4-0.4	
2 Bamboo (<i>Bambusa nana</i>) ²	22.5	22-8.5		2 Delicious ¹	27	7.2-4.5	0.45-0.92
3 Barley (<i>Hordeum vulgare</i>)	23	26.6(11.6)	0.85	3 Maiden blush ²	25	4.2-20	
4 Barley (<i>H. vulgare</i>), etiolated	23	21.6(11.2)	0.83	4	0	1.4-2.4	
5 Bean (<i>Phaseolus vulgaris</i>)	26	26-57		5 Winesap ²	25	1.9-0.9	
6 Beech (<i>Fagus sylvatica</i>)	21	34		6	0	1.8-0.6	
7 Beet (<i>Beta vulgaris</i>)	27	23		7 Apricot (<i>Prunus armeniaca</i>) ²	18	2.8-4.1	
8 Begonia (<i>Begonia rex</i>)	20	30		8	4	1.1-1.0	
9 Broadbean (<i>Vicia faba</i>), blade	RT	11.1(5.1)		9 Avocado (<i>Persea gratissima</i>) ²	5	1	
10 Broadbean (<i>V. faba</i>), petiole	RT	4.1(4.3)		10	25	7-15	
11 Broom (<i>Spartium junceum</i>), blade	RT	17	0.71	11 Banana (<i>Musa paradisica sapientum</i>)	31	3.1	
12 Buttercup (<i>Ranunculus glacialis</i>)	20	28		12	20	1.8	
13	10	19		13	12.5	0.9	
14	0	5.1		14	0	0.4	
15 Catalpa (<i>Catalpa bignonioides aurea</i>)	14	18		15 Barberry (<i>Berberis vulgaris</i>)	25		1.20
16 Catalpa (<i>C. bignonioides koehnei</i>)	14	25		16 Bean (<i>Phaseolus vulgaris</i>) ²	24	16.4-6.6	1.1-1.0
17 Cattail (<i>Typha latifolia</i>) ²	22.5	26-15-19		17	0.5	0.95-0.6	0.94-0.96
18 Charlock (<i>Raphanus raphanistrum</i>), blade	RT	13.3	0.73	18 Bryony (<i>Bryonia dioica</i>) ¹	25	64-8.5	
19 Charlock (<i>R. raphanistrum</i>), petiole	RT	6.2	0.86	19 Cherry (<i>Prunus avium</i>) ¹	20	68-2	
20 Cinquefoil (<i>Potentilla reptans</i>), blade	RT	31.9(12.5)	0.67	20 Corn (<i>Zea mays</i>) ¹	30	21-18(12-9)	
21 Cinquefoil (<i>P. reptans</i>), petiole	RT	10.7(5.6)	0.83	21 Cranberry (<i>Vaccinium</i>) ¹	24	32-14	
22 Coffee (<i>Coffea arabica</i>)	20	1.5 ³		22 Cucumber (<i>Cucumis sativus</i>) ²	24	2.3-0.8	1.01-0.91
23 Corn (<i>Zea mays</i>)	26	68(17.1)	0.99	23	10	1.0-0.4	1.01-1.10
24 Corn (<i>Z. mays</i>), etiolated	26	54(18.1)	0.97	24	0.5	0.2-0.7	0.97-0.88
25 Dandelion (<i>Taraxacum officinale</i>)	19	46	0.95	25 Elder (<i>Sambucus nigra</i>)	18	12(11)	
26 Duckweed (<i>Lemna minor</i>)	25	300 ⁴		26 Grape (<i>Vitis vinifera</i>)	28		1.6
27 Elm (<i>Ulmus montana</i>)	16	24		27 Grapefruit (<i>Citrus grandis</i>)	38	2.5	2.1
28 Elm (<i>U. montana aurea</i>)	16	22		28	21	1.0	1.1
29 Elm (<i>U. montana atropurpurea</i>)	16	23		29	10	0.4	1.4
30 Eucalyptus (<i>Eucalyptus globulus</i>)	19	8.5	0.80	30	0	0.1	1.2
31 Gladiolus (<i>Gladiolus gandavensis</i>)	24	18	0.64	31 Guava (<i>Psidium guajava</i>) ²	30	20-3.6	
32 Horsechestnut (<i>Aesculus hippocastanum</i>)	12	49		32 Hawthorn (<i>Crataegus punctata</i>)	20	13-50-19	1.26
33 Horsechestnut, white (<i>A. hippocastanum</i>)	12	26		33 Ivy (<i>Hedera helix</i>) ¹	38	4.1	1.4
34 Ivy (<i>Hedera helix</i>)	32	40	1.00	34 Lemon (<i>Citrus limonia</i>)	10	0.5	1.1
35	18	18	1.00	35	0	0.15	1.2
36 Lettuce (<i>Lactuca sativa</i>) ²	24	3.3-2.6	1.12-1.02	36 Lilac (<i>Syringa vulgaris</i>) ¹	25	42-8.5	
37	10	1.3-0.7	1.09-1.00	37 Oak (<i>Quercus alba</i>)	30	14.9 ³	0.71
38	0.5	0.95-0.4	0.88-0.98	38	10	4.8 ³	0.30
39 Lime (<i>Citrus aurantium</i>)	20	3.0 ³		39	2.5	2.7 ³	0.16
40 Mallow (<i>Malva parviflora</i>), blade	RT	32	0.84	40	30	6.4 ³	0.46
41 Mallow (<i>M. sylvestris</i>), blade	RT	12.3	0.71	41 Oak (<i>Q. rubra</i>)	10	3 ³	0.13
42 Maple (<i>Acer pseudoplatanus</i>)	10	33		42	2.5	1.6 ³	0.08
43 Maple (<i>A. pseudo. atropurpureum</i>)	16	23		43 Okra (<i>Hibiscus esculentus</i>) ²	30	306-104	
44 Maple (<i>A. pseudo. cupreum</i>)	16	24		44	28		1.07
45 Maple (<i>A. pseudo. luteo-virescens</i>)	10	28		45 Orange (<i>Citrus nobilis</i>)			
46 Mullein (<i>Verbascum thapsus</i>)	26	38	0.84	46			
47 Nettle (<i>Urtica membranacea</i>), blade	RT	10.8	0.69	47 Washington navel	21	2.0	1.1
48 Nightshade (<i>Solanum nigrum</i>), blade ²	16	34-10	0.78-0.67	48	10	0.8	1.1
49 Olive (<i>Olea europaea</i>) ²	22	24-13	0.78-0.75	49	0	0.2	1.2
50 Optunia (<i>Optunia versicolor</i>)	65	6		50	38		1.7
51	55	21		51	21	1.8	1.0
52	45	33		52	0	0.2	1.1
53	35	15	0.70	53 Papaya (<i>Carica papaya</i>)	15.6	0.83	
54 Pine (<i>Pinus canariensis</i>)	29	42	0.90	54	10	0.46	
55 Pine (<i>P. maritima</i>)	36	5	0.87	55	4.4	0.24	
56	20	12	0.84	56	24	20-12	1.32-1.06
57	0	2	0.83	57	10	7.9-3.1	1.13-1.00
58 Potato (<i>Solanum tuberosum</i>)	48	137		58	0.5	2.2-1.4	1.00-0.96
59	30	41		59	18	1.4-2.0 ²	
60 Purslane (<i>Atriplex hortensis</i>)	18	44		60	4	0.4-0.3 ²	
61 Reed (<i>Phragmites communis</i>) ²	22.5	31-12		61	25	7-5 ¹	
62 Rye (<i>Secale cereale</i>)	25	44		62	25	8-2 ²	
63	15	26		63	18	6.3-1-1.2 ¹	
64 Sorrel (<i>Rumex acetosa</i>), blade	RT	21.6	0.76	64	18	1-0.9-2.2 ²	
65 Sorrel (<i>R. pulcher</i>), blade	RT	14.7	0.76	65	24	4.0-1.4	1.12-0.88
66 Spinach (<i>Spinacia oleracea</i>) ²	24	16.2-12.8	0.94-0.83	66	10	1.2-0.6	1.27-0.88
67	10	4.2-2.0	0.90-0.86	67	0.5	0.4-0.3	0.96-0.96
68	0.5	1.5-5.8	0.85-0.73	68 Persimmon, Hachiya (<i>Diospyros kaki</i>)	20-27	1.8	1.2
69 Squill (<i>Scilla peruviana</i>)	20	4	0.78	69 Persimmon, Fuyu (<i>D. kaki</i>)	20-27	1.4	1.1
70 Sunflower (<i>Helianthus annuus</i>)	42	24.3 ³		70 Pigeon pea (<i>Kajanus indicus</i>) ¹	21	30-0	
71	31	16.6 ³		71 Pimento (<i>Pimenta officinalis</i>)	30	40 ³	
72	20	5.8 ³		72 Plum (<i>Prunus domestica</i>)	18	8.7(5.6)	
73 Tea (<i>Thea sinensis</i>), sections	36	16.4(8.6)		73 Poppy (<i>Papaver somniferum</i>)	20	38	1.5
74 Tomato (<i>Lycopersicon esculentum</i>)				74 Rye (<i>Secale cereale</i>) ¹	28	[240-12] ³	
75	28	260 ⁴		75 Smartweed (<i>Polygonum scandens</i>)	30		0.87
76 Vetch (<i>Vicia sativa</i>), blade	RT	30.1	0.75	76 Strawberry (<i>Symphoricarpos ramosus</i>) ¹	17	33	
77 Vetch (<i>V. sativa</i>), petiole	RT	16.7	0.88	77 Strawberry, missionary (<i>Fragaria sp.</i>)	20	3.3-5.1	0.84-0.91
78 Vetch (<i>V. sativa</i>), tendrill	RT	27.7	0.90	78 Strawberry (<i>F. vesca</i>)	28		1.27
79 Wheat (<i>Triticum aestivum</i>)	25	40(10.6)	0.97	79 Tobacco (<i>Nicotiana tabacum</i>)	28		0.94
80 Wheat (<i>T. aestivum</i>), etiolated	25	38(11.7)	0.98	80 Tomato (<i>Lycopersicon esculentum</i>)	24	2.5-1.6 ²	1.11-1.13
81 Yew (<i>Taxus baccata</i>)	46	55	0.89	81	10	0.8-0.6 ²	1.39-1.06
82	16	6	0.86	82	0.5	0.4-0.2 ²	1.11-1.02
83 Yucca (<i>Yucca gloriosa</i>) ²	22.5	13.6-5.1		83	28	2.6-2.5 ¹	1.8-1.4
				84	28	[340-8] ³	

/1/ RT = room temperature. /2/ Material observed under conditions of storage or starvation. /3/ $\mu\text{l}/\text{sq cm}/\text{hr}$. /4/ $\mu\text{l}/100\text{ mg dry wt}/\text{hr}$.

/1/ Data show changes during growth, development, maturation. /2/ Material observed under conditions of storage or starvation. /3/ $\mu\text{l}/100\text{ mg dry wt}/\text{hr}$.

244. RESPIRATORY MEDIA: CHARACTERISTICS

Water and nitrogen are the two major ecological variations of respiratory media available to organisms. These media are the solvents, mechanically inspired by the actively ventilated respiratory organ, through which occurs the exchange of oxygen and carbon dioxide. Values identified with an asterisk (*) are averages of many determinations but vary widely with conditions of measurement.

Variable	Water		Atmosphere (N ₂)	
	Ocean	Fresh	Sea Level	Altitude ¹
1 Temperature, °C	-2.0 to 30.0	2.0-32.0	0.7-15.7	-28.1 to -15.1
2 Pressure, total, mm Hg	760-760,000	760-20,000	760	347.5-360.2
3 Density, g/L	1027* (20°C)	1000* (4°C)	1.223-1.290	0.649-0.659
Concentration				
4 H ₂ O, vol %	100.00	100.00	1.00 ²	1.00 ²
5 N ₂ , vol %	1.03* (15°C)	1.33* (15°C)	78.03 (STP)	78.03 (STP)
6 CO ₂ , vol %	0.02* (15°C)	0.03* (15°C)	0.03 (STP)	0.03 (STP)
7 O ₂ , vol %	0.58* (15°C)	0.72* (15°C)	20.99 (STP)	20.99 (STP)
8 Salts, vol %	3.46*	0.18*		
9 pH	7.5-8.4	3.2-10.6		
10 Inert gases, vol %	Trace	Trace	0.95 (STP)	0.95 (STP)
Partial Pressure (Tension)				
11 H ₂ O (mm Hg)	12.79 (15°C)	6.10 (4°C)	6.40 ³ (15°C)	0.72 ³ (-15°C)
12 N ₂ (mm Hg)	593.02 (STP)	593.02 (STP)	593.02 (STP)	281.06 ⁴ (STP)
13 CO ₂ (mm Hg)	0.23* (STP)	0.23* (STP)	0.23 (STP)	0.11 ⁴ (STP)
14 O ₂ (mm Hg)	159.52* (STP)	159.52* (STP)	159.52 (STP)	75.61 ⁴ (STP)
15 Inert gases	7.46 (STP)	7.46 (STP)	7.46 (STP)	3.42 ⁴ (STP)
16 Total pressure	760.00	760.00	760.00	360.20
Diffusion Coefficient ml/min/sq cm x cm (760 mm Hg, 20°C)				
17 H ₂ O		0.000018 ⁵ (0.53) ⁶		
18 N ₂		0.000785 ⁵ (23.1) ⁶		
19 CO ₂		0.00034 ⁵ (1.0) ⁶	11.0	
20 O ₂				

/1/ 6000 meters. /2/ Varies, but never absent and always of biological significance. /3/ Calculated for 50% relative humidity. /4/ Calculated from Lines 5, 6, 7, 10 and 16. /5/ Calculated from measured value for O₂ (Line 20) and relative coefficients (Lines 18, 19). Values in parentheses are relative coefficients with O₂ as unity.

245. RESPIRATORY MOLECULES: CHARACTERISTICS

Values, unless otherwise indicated, are for standard conditions (STP) of temperature (0°C) and pressure (760 mm Hg).

Type	Weight (0=16)	Diameter ¹ cm x 10 ⁻⁸	Density g/L	Mean Free Path cm x 10 ⁻⁶ (750 mm Hg)	Collision Frequency (20°C)	Average Velocity cm x 100/sec	Water Solubility		Vol % (40°C)
							STP	20°C	
1 N ₂	28.02	3.15-3.53	1.251	8.50	5070	454	2.35	1.54	1.18
2 H ₂ O	18.02	3.0-5.0	0.005-0.030 ²			566			
3 CO ₂	44.01	3.34-3.40	1.977	5.56	6120	362	171.3	87.8	53.0
4 O ₂	32.00	2.92-2.98	1.429	9.05	4430	425	4.89	3.10	2.31

/1/ Range indicates variability with method of measurement (e.g. viscosity, heat conductivity). /2/ Water vapor in saturated air, i.e., in equilibrium with water, at 0°C and 30°C.

246. RESPIRATORY EXCHANGE CHARACTERISTICS: MAN

Part I: VENTILATION

Gas	Inspired Air		Alveolar Air		Expired Air	
	Composition vol % ¹	Partial Pressure mm Hg ²	Composition vol % ^{1, 3}	Partial Pressure mm Hg ^{3, 4}	Composition vol % ¹	Partial Pressure mm Hg ⁴
A	B	C	D	E	F	G
1 H ₂ O	0.00	5.7	00.0	47	00.0	47
2 N ₂	79.02	596.0	80.4	573	79.2	565
3 O ₂	20.95	158.0	14.0	100	16.3	116
4 CO ₂	0.03	0.3	5.6	40	4.5	32

/1/ Dry air, partial pressure in mm Hg, = B/100 x 760 mm Hg (Dalton's Law). /2/ Ambient air (slight variations exist), in vol %, = 100 C/760 (Dalton's Law). /3/ "Alveolar" air, actually last part of expired samples. /4/ Physiological air, normal temperature (37°C) and standard pressure (760 mm Hg).

Part II: TRANSPORT

Values in parentheses are ranges.

Gas	Arterial		Capillary		Tissue Fluid		Venous	
	vol %	mm Hg	vol %	mm Hg	vol %	mm Hg	vol %	mm Hg
1 H ₂ O	83(81-86)	47	83(81-86)	47	83(81-86)	47	83(81-86)	47
2 N ₂	0.975	573	0.975	573	0.975	573	0.975	573
3 O ₂	19.6(17.3-22.3)	94	1-22.3 ¹	1-94 ¹	0.185 ¹	30 ¹	12.9(11.0-16.1) ²	40
4 CO ₂	48.2(44.6-50.4)	40	44.6-57.7 ¹	40-50	3.046 ¹	50 ¹	54.8(51.0-57.7) ²	46

/1/ Variable, depending on blood flow, tissue activity and relation of sample to capillary length or field. /2/ Internal jugular.

247. RESPIRATORY EXCHANGE CHARACTERISTICS: VERTEBRATES

Volume per cent values are for dry air.

Animal	Inspired Air vol %		Alveolar Air vol %		Expired Air vol %		RQ
	O ₂	CO ₂	O ₂	CO ₂	O ₂	CO ₂	
1 Man (Homo sapiens)	20.95	0.03	14.00	5.60	16.30	4.50	0.850
2 Dog (Canis familiaris)			13.66	5.68	16.30	3.46	0.780
3 Albino rat (Rattus norvegicus)							0.894 (0.754-1.072)
4 Horse (Equus caballus)							0.960
5 Guillemot (Cepphus grylle)					15.05	4.83	
6 Chicken (Gallus domesticus)					13.50	6.50	0.764 ¹ (0.71-0.96) ²
7 Turtle (28°C) (Malaclemys centrata)			16.46	4.69			0.71 ³
8 Frog (20°C), cutaneous (Rana esculenta)							1.92
9 Frog (20°C), pulmonary (R. esculenta)							0.32
10 Puffer fish (20°C)	0.31		0.31		0.149		

/1/ Average for 5 days including day of last feeding. /2/ Range for 1-5 hr and 4 days after feeding. /3/ Data for painted turtle (Chrysemys marginata) included in calculation.

248. LUNG VENTILATION: VERTEBRATES

Values, unless otherwise noted, are averages of means for the resting state. Ranges in parentheses are estimate "d" of the 95% range (cf Introduction).

Species	Respiration Frequency breath/min	Tidal Volume ¹ ml	Minute Volume ² L
1 Man (<i>Homo sapiens</i>)			
2 Premature	33	12.4(8.4-17.3)	0.41(0.28-0.58)
3 Newborn, asleep	43(24-116)	16.7(10.0-27)	0.72(0.43-1.41)
4 Adult ♂	11.7(10.1-13.1) ³	750(757-895) ⁴	7.4(5.8-10.3) ⁵
5 ♀	11.7(10.4-13.0) ⁶	339(285-393) ⁷	4.5(4.0-7.0) ⁸
6 Cat (<i>Felis catus</i>)	26	12.4	0.32
7 Cow (<i>Bos taurus</i>)	31(27-40)	2850(2200-3800)	86(59-104)
8 Dog	18(11-38)	320(251-432)	5.2(3.3-7.4)
9 Goat	19.0	310	5.7
10 Guinea pig (<i>Cavia cobaya</i>)	90(69-104)	1.8(1.0-3.9)	0.16(0.09-0.38)
11 Hamster (<i>Mesocricetus auratus</i>)	74(33-127)	0.83(0.42-1.2)	0.054(0.025-0.083)
12 Horse (<i>Equus caballus</i>) ⁹	11.9(10.6-13.6)	9000(8520-9680)	107
13 Manatee, Florida (<i>Trichechus latirostris</i>)	7.0(6.0-8.0)	(5000-9000)	45(35-60)
14 Marmot (<i>Marmota marmota</i>)	8.0 ¹⁰	22.0 ¹¹	0.17 ¹²
15 Monkey (<i>Macaca mulatta</i>)	40(31-52)	21(9.8-21)	0.86(0.31-1.41)
16 Mouse (<i>Mus musculus</i>)	163(84-230)	0.15(0.09-0.23)	0.023(0.011-0.036)
17 Porpoise (<i>Tursiops truncatus</i>)	1.1(0.9-1.3)	9,000(8,000-10,000)	9.7(9.0-10.4)
18 Rabbit (<i>Lepus cuniculus</i>)	51(38-60)	21(19.3-24.6)	1.07(0.80-1.14)
19 Rat (<i>Rattus norvegicus</i>)		1.5(1.4-1.6)	0.100(0.075-0.130)
20 Rat, cotton (<i>Sigmodon hispidus</i>)	94(75-115)	0.35(0.24-0.70)	0.04(0.023-0.071)
21 Sloth (<i>Choleopus hoffmanni</i>)	13.0		0.84(0.80-1.0)
22 Sloth (<i>Bradypus griseus</i>)	(4.5-8.0)		0.49(0.33-0.73)
23 Turtle (<i>Maclermys centrata</i>)	3.7	14.0	0.05

/1/ Air inspired per breath. /2/ Respiration frequency x tidal volume. /3/ Resting. Light work, 17.1(15.7-18.2); heavy work, 21.2(18.6-23.3). /4/ Resting. Light work, 1670(1510-1770); heavy work, 2030(1900-2110). /5/ Resting. Light work, 29(27-31); heavy work, 60(50-90). /6/ Resting. Light work, 19; heavy work, 30(25-33). /7/ Resting. Light work, 860(836-885); heavy work, 880(490-1270). /8/ Resting. Light work, 16.3(15.9-16.8); heavy work, 24.5(17.3-32.0). /9/ Percheron, gelding. /10/ Hibernating, 0.68. /11/ Hibernating, 13(11.3-15.0). /12/ Hibernating, 0.009.

249. PULMONARY VALUES, EQUATIONS, DEFINITIONS: MAN

Part I: LUNG AIR VOLUME, RECUMBENT
Values are from smoothed curves plotted from mean values, and are for the following conditions: 37°C, ambient pressure, saturated with water vapor. Ranges in parentheses are from smoothed curves of ranges, and are estimate "d" of the 95% range (cf Introduction).

Age yr	Total Lung Capacity ¹ L	Vital Capacity ² L
1 Six ♂	1.6(1.3-2.1)	1.2(0.9-1.7)
2 ♀	1.6(1.3-2.1) ³	1.2(0.9-1.7) ³
3 Ten ♂	2.5(2.2-3.1)	1.9(1.6-2.4)
4 ♀	2.5(2.2-3.1) ³	1.9(1.6-2.4) ³
5 Fourteen ♂	4.6(3.5-6.1)	3.7(3.0-4.7)
6 ♀	3.6(2.8-4.3) ³	2.7(2.2-3.5) ³
7 Eighteen ♂	5.9(4.3-8.0)	4.6(4.0-5.8)
8 ♀	4.1(3.1-5.3) ³	3.0(2.4-4.2) ³
9 Twenty ♂	6.3(4.3-8.5)	4.9(4.0-6.0)
10 ♀	4.2(3.1-5.3) ³	3.0(2.4-4.4) ³
11 Twenty-five ♂	6.4(4.3-9.0)	4.9(3.3-6.0)
12 ♀	4.2(3.1-5.4)	3.0(2.2-4.2) ³
13 Thirty-five ♂	6.1(4.3-8.5)	4.5(2.3-6.0)
14 ♀	4.3(3.0-5.6)	3.0(2.0-3.8)
15 Forty-five ♂	5.9(4.3-8.0)	4.3(2.8-5.1)
16 ♀	4.3(2.9-5.7)	2.9(1.8-3.7)
17 Fifty-five ♂	5.8(4.3-8.0)	4.1(2.6-5.5)
18 ♀	4.2(2.8-5.7)	2.7(1.6-3.5)
19 Sixty-five ♂	5.6(4.3-7.0)	3.7(2.5-5.0)
20 ♀	3.9(2.8-5.5) ³	2.3(1.4-3.4) ³
21 Seventy-five ♂	5.2(4.3-7.0)	3.3(2.5-4.5)
22 ♀	3.9(2.8-5.0) ³	2.2(1.4-3.3) ³

/1/ Total volume of air contained in lungs after deepest possible inspiration. Total lung capacity minus vital capacity equals residual capacity or residual air. /2/ Volume of air expired in deepest possible expiration following deepest possible inspiration. /3/ Values are estimates; a sex difference may exist.

Part II: INTRAPULMONIC (INTRA-ORAL) PRESSURE
Values are for males only. Mean lung volumes are given as per cent of vital capacity. Ranges in parentheses are estimate "b" of the 95% range (cf Introduction).

Volume %	mm Hg
Maximum Expiratory Pressure	
1 9.7	42(14.7-68)
2 25.0	52(10.9-94)
3 44	70(30-109)
4 60	90(47-133)
5 75	93(58-128)
6 83	107(74-144)
7 100	120(86-145)
Maximum Inspiratory Pressure	
8 3.9	86(47-125) ¹
9 21.7	75(46-103) ¹
10 35	63(26-101) ¹
11 56	57(26-88) ¹
12 76	45(16.8-73) ¹
13 91	24(2.2-49) ¹
Relaxation Pressure	
14 0	-19.2(-32 to -6.6)
15 13.9	-8.5(-15.5 to -1.5)
16 31	-1.3(-9.9 to 7.3)
17 51	4.1(-1.9 to 10.1)
18 72	10.5(1.9 to 19.1)
19 87	14.9(0.3 to 29.5)
20 100	20.6(10.2 to 31)

/1/ Negative pressure.

Part IV: PREDICTION EQUATIONS

Equations are applicable for the following conditions: 37°C, ambient pressure, saturated with water vapor. MBC=maximum breathing capacity, L/min; SA=body surface area, sq m; V=pulmonary ventilation, L/min; W=weight, kg; VC=vital capacity, L; H=height, cm; A=age, yr.

Subject	Equation
1 Infants, <1 week, resting	$V = 0.139 + 0.00367 W^{1/4}$
2 Males, 10-17 yr	$VC = 0.0562 H + 0.0097 AW - 6.27$
3 140-160 cm	$VC = 0.0492 H - 4.82$
4 160-190 cm	$VC = 0.0799 H - 9.75$
5 Males, standing	$VC = 0.025 H^2$
6 Females, standing	$VC = 0.020 H^2$
7 Males	$MBC = [86.5 - (0.522 \times A)] \times SA^3$
8 Females	$MBC = [71.3 - (0.474 \times A)] \times SA^3$
9 Both sexes	$MBC = H \times (1.24 - 0.0095 A)^3$

/1/ Weight in ounces. /2/ Age correction for vital capacity: 46-55 yr = -4%; 56-65 yr = -8%; 66-75 yr = -16%; over 75 yr = -30%. /3/ Values vary widely with equipment and laboratory methods.

Part III: INTRAPLEURAL PRESSURE

Values are cm H₂O relative to atmospheric pressure.

Condition	Inspiration	Expiration
1 Adults, at rest	-5 to -10	-3 to -5
2 Deep breathing	-30	
3 Müller's ¹	-50 to -60	
4 Valsalva's ²		60
5 Normal ³	-0.7(-0.5 to -1.0)	0.4(0-1.0)
6 Labored ³	-1.1(-0.5 to -1.5)	2.4(1.0 to 3.0)
7 Normal ⁴	-1.3(-1.0 to -1.5)	2.6(1.0 to 3.5)
8 Infants, end of inspiration	-5	
9 End of expiration		0

/1/ Inspiration with glottis closed. /2/ Expiration with glottis closed. /3/ Air pressure at posterior pharynx. /4/ Air pressure at tracheal bifurcation.

249. PULMONARY VALUES, EQUATIONS, DEFINITIONS: MAN (Concluded)
 Part V: SUMMARY OF VALUES USED IN EVALUATION OF
 PULMONARY FUNCTION

Variable	Average "Normal" ¹ Values for Men
1 Maximal breathing capacity (MBC)	100-150 liters/min.
2 Vital capacity (VC)	3500-5000 cc.
3 Residual air	1000-1500 cc.
Ventilation volume per min/sq m BSA	
4 Rest	2.6-3.8 liters
5 Exercise	8.0-10.5 liters
Oxygen uptake from air breathed	
6 Rest	4.0-5.0% (40-50 cc/liter).
7 Exercise	5.0-6.0% (50-60 cc/liter).
Carbon dioxide addition to air breathed	
8 Rest	3.2-4.0% (32-40 cc/liter).
9 Exercise	3.4-4.2% (34-42 cc/liter).
Arterial blood	
Carbon dioxide content ²	
10 Rest	48.5 vol %.
11 Exercise	42.5 vol %.
Oxygen content ²	
12 Rest	19.0 vol %.
13 Exercise	19.2 vol %.
Hemoglobin saturation	
14 Rest	96+ %.
15 Exercise	96+ %.
Mean resting tensions ³	
16 Oxygen (pO ₂)	95 mm Hg.
17 Carbon dioxide (pCO ₂)	40 mm Hg.
18 Dyspnea following mild exercise ⁴	60 seconds.

/1/ Pathological findings: pulmonary fibrosis, as in silicosis, tuberculosis, bronchiectasis, sarcoidosis, post-radiation fibrosis, pleuritis, hydrothorax, spondylitis and kyphoscoliosis, causes pulmonary insufficiency; the findings are reduction in lung volumes and maximum breathing capacity, normal spiogram, hyperventilation, low blood carbon dioxide and high arterial pH. In emphysema residual air is increased. Maximum breathing capacity and vital capacity are reduced; arterial oxygen content is low, while carbon dioxide content is elevated. In pulmonary edema arterial anoxia results from disturbance of diffusion of gases across the alveolocapillary membrane. Pulmonary hypertension occurs in emphysema, cardiac failure, mitral stenosis, Ayerza syndrome and polycythemia. /2/ Van Slyke method. /3/ Riley method. /4/ 30 step-ups in one min on stool 20 cm high.

Part VI: STANDARDIZED NOMENCLATURE IN RESPIRATORY PHYSIOLOGY

Standardized Measurement	Previous Measurement
1 Inspiratory reserve volume	Complemental air. Complementary air. Complemental air minus tidal air. Inspiratory capacity minus tidal volume.
2 Expiratory reserve volume	Supplemental air. Reserve air.
3 Tidal volume	Tidal air.
4 Residual volume	Residual air. Residual capacity.
5 Vital capacity	Vital capacity.

Part VII: STANDARD SYMBOLS IN
 RESPIRATORY PHYSIOLOGY

Symbol	Variable ¹
General	
1 V	Gas volume in general. (Pressure, temperature and % saturation with H ₂ O vapor to be stated.)
2 \dot{V}	Gas volume per unit time.
3 P	Gas pressure in general.
4 F	Fractional concentration in dry gas phase.
5 \dot{Q}	Quantity flow of blood.
6 C	Concentration in blood phase.
7 F	Respiratory frequency-breaths per unit time.
8 R	Respiratory exchange ratio in general (vol CO ₂ /vol O ₂).
9 D	Diffusing capacity in general (volume per unit time per unit pressure difference).
Gas Phase	
10 I	Inspired gas.
11 E	Expired gas.
12 A	Alveolar gas.
13 T	Tidal gas.
14 D	Dead space gas.
15 B	Barometric.
Blood Phase	
16 b	Blood in general.
17 a	Arterial (exact location to be specified).
18 v	Venous (exact location to be specified).
19 c	Capillary (exact location to be specified).
Special	
20 X	Dash above any symbol indicates a mean value.
21 \dot{X}	Dot above any symbol indicates a time derivative.
22 S	Subscript to denote the steady state.
23 STPD	Standard temperature, pressure, dry. (0°C, 760 mm Hg).
24 BTPS	Body temperature, pressure, saturated with water.
25 ATPD	Ambient temperature, pressure, dry.
26 ATPS	Ambient temperature, pressure, saturated with water.

/1/ Definitions, dimensions and conditions must be specified.

Part VIII: GLOSSARY

TIDAL VOLUME: Volume of air inhaled and exhaled during a single quiet cycle. Wide variability in clinically normal individuals reduces the significance of this determination and complicates its interpretation. INSPIRATORY RESERVE VOLUME: Some investigators consider total volume of air from the beginning of quiet respiration and others from the conclusion of quiet respiration. EXPIRATORY RESERVE VOLUME: Volume of air that can be forcibly expired following a quiet expiration. VITAL CAPACITY: Sum of tidal and inspiratory and expiratory reserve volumes. The volume obtained may be any volume but to be of value should be compared to the "normal" standard tables based on surface area, weight, or standing height. RESIDUAL VOLUME: Air in lungs following a full forced expiration. Included with this volume is the minimal air volume which, although present in the alveoli, cannot be readily measured. TOTAL LUNG CAPACITY: Total volume of air in lungs after full inspiration. FUNCTIONAL RESIDUAL CAPACITY: Air present within lungs at midpoint during a quiet respiration; also classified as midcapacity and subtotal volume. RESTING MINUTE VENTILATION: Total volume of air ventilated in one minute under conditions of rest. It varies widely with individuals but rarely in any one individual. MAXIMUM MINUTE VENTILATION: Maximum volume of air ventilated in one minute in conditions of forced breathing (also known as maximum minute volume). VENTILATORY FACTOR: Quotient of maximum minute ventilation divided by resting minute ventilation, but value is widely variable. Inasmuch as the minute resting ventilation is fixed for an individual, its division into the maximum minute ventilation gives a fairly accurate value for the ventilatory factor. The ventilatory factor may be greatly reduced before appearance of dyspneic symptoms upon exertion.

250. ARTIFICIAL RESPIRATION: MANUAL

Values are mean tidal volumes in cu cm/cycle obtained with manual methods of artificial respiration. They are the results of comparative studies on various types of non-breathing human subjects.

Method	Warm Corpses ^{1,2}	Passive Suspension of Respiration ^{1,3}	Apnea				Conscious, Passive ⁹	
			Induced by Curare- pentothal-cyclo- propane Mixture ^{1,4}	Induced by Anesthesia and Curare Drugs ^{5,6}	Intra-cranial Pathology ^{5,7}	Intra- cranial Pathology ⁸	Male	Female
1 Prone pressure (Schafer)	185	810	485		155	365	466	296
2 Hip Lift (Emerson)	270	88.3	635			352	871	753
3 Silvester (Arm-lift chest-pressure)	520	1529	1069		285		1087	795
4 Back-pressure arm-lift (Holger Nielsen)	580	1367	1056	474	245	577	1060	748
5 Hip-roll back-pressure	537	1417	967		350		1140	858
6 Hip-lift back-pressure	530	1650	1140	864	405	680		

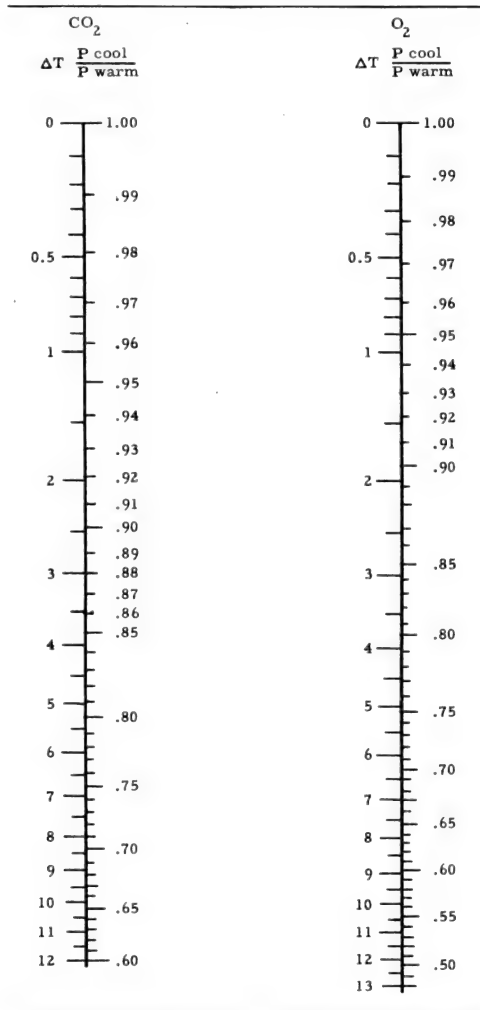
/1/ University of Illinois investigation. /2/ 26 subjects immediately after death and before onset of rigor mortis. /3/ 10 normal adult male subjects. /4/ 26 normal adult males. /5/ University of Pennsylvania investigation. /6/ 8 pre-operative patients. /7/ 4 patients. /8/ Harvard University investigation; 6 patients. /9/ Springfield College investigation; 15 normal males, 11 normal females.

251. RESPIRATORY CHARACTERISTICS: EFFECT OF TEMPERATURE

Part I: TEMPERATURE CHANGES VS. CO₂ AND O₂ TENSIONS

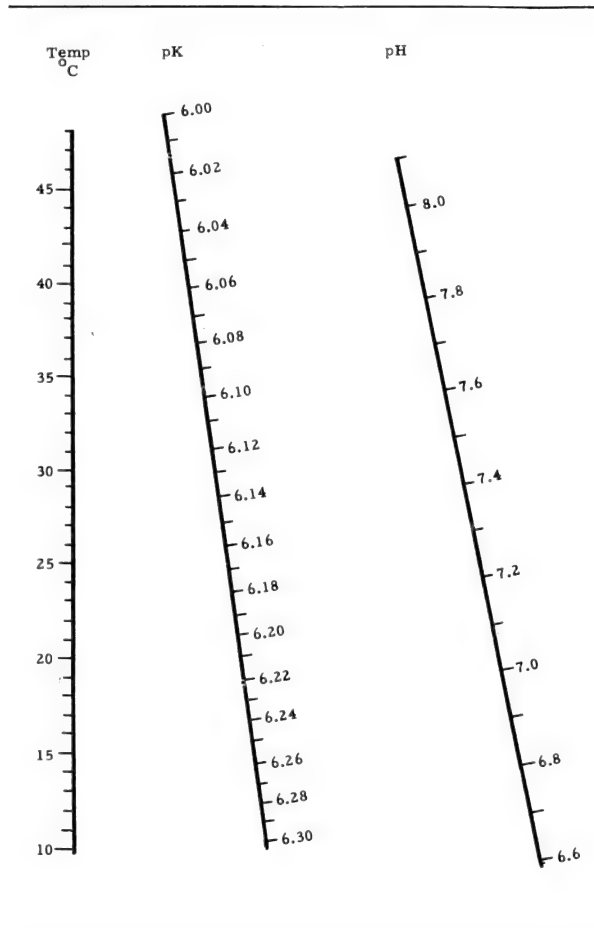
This nomogram illustrates the effect of changes in temperature on CO₂ and O₂ tensions in human or dog blood sealed in an anaerobic environment. The values are applicable to either in vitro or in vivo conditions as, for example, blood sampled into an oil-filled syringe, or blood cooling as it flows through an artery. Nomogram error increases progressively as pH and temperature deviate from standard values of 7.4 and 37°C respectively.

ΔT = temperature change in °C.



Part II: CALCULATION OF SERUM pK

This nomogram allows for calculation of serum pK' for carbonic acid in man and dog when pH and temperature are known. Mean pK' at 37.5°C and pH 7.40 = 6.090.



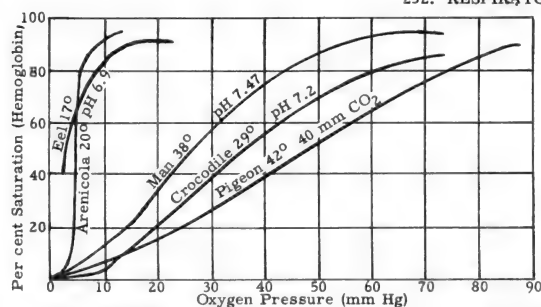
Part III: EFFECT OF BODY TEMPERATURE ON ARTERIAL pH and CO₂ TENSION: DOG

These values illustrate the effect of body temperature on arterial pH and CO₂ tension when tidal volume and rate are constant during cooling in curarized dogs.

Measurement	At 37°C	At 25°C	Measurement	At 37°C	At 25°C	Measurement	At 37°C	At 25°C
1 Oxygen consumption, ml/min	56	18	3 Plasma CO ₂ content, mM/L	19.7	16.5	5 Alveolar pCO ₂ , mm Hg (end expiratory)	35	19
2 pH	7.28	7.37	4 Arterial blood pCO ₂ , mm Hg	40	23 ¹			

/1/ The pCO₂ in normal blood (37°, pH 7.4, pCO₂ 40) when cooled anaerobically to 25° is, by coincidence, also 23 mm Hg.

252. RESPIRATORY CHARACTERISTICS: BLOOD



The oxygen tension, in mm Hg, at which the respiratory blood pigment (hemoglobin, unless otherwise indicated) is 95 or more per cent saturated, is referred to as the tension of saturation; that at which the pigment is 50% saturated (i.e., when unoxygenated pigment equals oxygenated pigment) is called the tension of half-saturation and indicated as " $t_{\frac{1}{2}}$ sat." The tension of half-saturation for a specific pigment establishes the upper limit of tissue oxygen tension and the lower limit of environmental oxygen for the function of that pigment. When per cent saturation is plotted as ordinate against oxygen pressure as abscissa, the "position" (O_2 pressure required to produce 50% saturation) of the resultant dissociation curve differs from species to species, and varies greatly within the same species with changes in pH and temperature. The figure to the left illustrates dissociation curves for two animals whose blood has a low affinity for oxygen, i.e., a high $t_{\frac{1}{2}}$ sat (pigeon, crocodile), and for two others (arenicola, eel) showing a high affinity and low $t_{\frac{1}{2}}$ sat. In the table below, values in parentheses are extrapolations.

Species	pCO ₂ mm Hg	pH	Temp °C	$t_{\frac{1}{2}}$ sat mm Hg	Species	pCO ₂ mm Hg	pH	Temp °C	$t_{\frac{1}{2}}$ sat mm Hg
Mammalia					Amphibia (concluded)				
1 Man	142	7.0	37	(39)	67 Bufo		7.38	25.4	30
2	110	7.1	37	(35.5)	68 Cryptobranchus		7.38	25.4	18
3	84	7.2	37	32.2	69 Desmognathus	43	7.38	25.4	5
4	60	7.3	37	29.2	70 "Eel," congo			26	30
5	31	7.5	37	23.5	71 Frog, adult		7.3	25.4	27
6	22	7.6	37	21.0	72 Frog, tadpole		7.38	25.4	7
7	15	7.7	37	(18.5)	73 Triturus		7.38	25.4	7.5
8		7.4	0	(1.7)	Pisces				
9		7.4	10	(3.8)	74 Baiara	0		28	8
10		7.4	20	8.1	75 Bom-bom	0		28	11
11	(48)	7.4	30	16.2	76 Bowfin	0-1		15	4
12	(42)	7.4	40	31.5	77 Carp	1-2		15	5
13 Cat		7.4	37	38	78	30		18	13
14	44	7.4	37	35	79 Catfish	0-1		15	1.4
15 Dog		7.1	37	29.4	80 Cod	<0.3		14	15
16	38	7.4	37.5	28	81 Eel, salt-water	0.3		17	4
17	40		38	31.5	82 Eel, electric	0		28	12
18 Fox	40		37.5	37	83 Haimara	0		28	8
19 Goat, adult	50		38	28-33	84 Hassa	0		28	20
20 Goat, fetal	50		38	25	85 Mackerel	1		20	16
21 Goat, maternal	50		38	40	86	1	8.0	20	17
22 Horse	50	7.4	37.5	27	87 Plaice	0.3		16.5	12
23 Llama		7.4	39	20	88 Paku	0		28	12
24	43		38	22	89 Ray		7.38	25	26 ²
25 Marmot	40		38	23.8	90 Ray	1		25	45
26 Marten	40		38	38	91 Ray, sting		7.4	25.5	13-15 ²
27 Mink	40		37	37	92 Scup		7.38	25	6.4 ²
28 Mouse	40		38	72	93 Sea robin		7.38	25	21 ²
29 Ox		(7.4)	37	29.8	94	1	7.7	20	17
30 Peccary		7.4	37	29	95 Shark	1		25	7
31 Porpoise	46		38	30	96 Shark, sand		7.4	25.5	7.6 ²
32 Rabbit	32	7.4	38.6	31.6	97 Shark, bonnet nose		7.4	25.5	7 ²
33 Rat		7.4	37	40	98 Salmon, fresh water	1-2		15	21
34 Rat, kangaroo	40		37	51	99 Salmon, brackish	1-2		15	23
35 Rat, white	40		37	56	100 Skate	1		0.2	11
36 Sea lion	44		38	40	101	1	7.8	10.4	20
37 Seal	40		38	31	102	1		25	45
38 Seal, harbor	40		37	28	103	1		37.5	98
39 Sheep		(7.4)	37	39	104 Sucker	1-2		15	12
40	40		39	37	105 Tautog		7.38	25	6 ²
41 Swine		(7.4)	37	33.7	106 Toadfish		7.38	25	3-4.4 ²
42 Vicuna		7.4	39	18	107	1	7.7	20	13
43 Viscacha		7.4	38.6	26	108 Trout, brook	1-2		15	17
Aves					109 Trout, common	0-3		15	18
44 Crow	40		42	53	110 Trout, rainbow	1-2		15	15
45 Duck, domestic	40		37.5	42	Invertebrata				
46 Duck, domestic		7.1	37.5	45	111 Arenicola	0	7.3	17	1.8
47 Fowl	37	7.4	40	51	112 Busycon ³	13.5		23	6
48	31		38	58	113 Cancer ³	0		23	12
49 Goose		7.1	37.5	45	114 Ceriodaphnia	0		17	0.8
50	50		42	37.5	115 Chironomus	0		17	0.2-0.6
51 Huallata		7.35	40	33	116 Daphnia	0		17	3.1
52 Ostrich		7.35	40	26	117 Gastrophilus	0		39	4.9
53 Pheasant		7.1	37.5	50	118	0		39	0.2 ²
54 Pigeon	40		37.5	35	119 Helix, summer ³	0	20	20	12
55	40		42	51	120 Helix, winter ³		8.2	20	11
Reptilia					121 Homarus ³		7.2		90
56 Alligator	42	7.6	20	28	122 Limulus ³		7.7		13
57 Chuckwalla	37	7.6	20	24	123 Loligo ³	0		23	36
58	(55)		37	62	124 Octopus ³	0.6		25	3
59 Crocodile	(50)	(7.4)	29	26	125 Phascolosoma ⁴			19	8
60	(45)	(7.4)	37	53	126 Planorbis	0		20	7
61 Gila monster	36	7.4	20	32	127	0		17	1.9
62	(32)	7.4	37	59	128 Sepia ³	2.3		25	14
63 Turtle	40		25	20	129 Sipunculus ⁴	0.07-80		19	8
64	27		25	28	130 Spirographis ⁵		7.7	20	27
65		7.4	25.5	20.3 ^{1,2}	131 Tubifex	0		17	0.6
Amphibia					132 Urechis ⁴	8.6		19	12.3
66 Amphiuma		7.38	25.4	15					

/1/ Inter-species range 12-28.5. /2/ Dilute hemoglobin solution. /3/ Hemocyanin. /4/ Hemerythrin. /5/ Chlorocruorin.

253. ACID-BASE BALANCE: VERTEBRATES

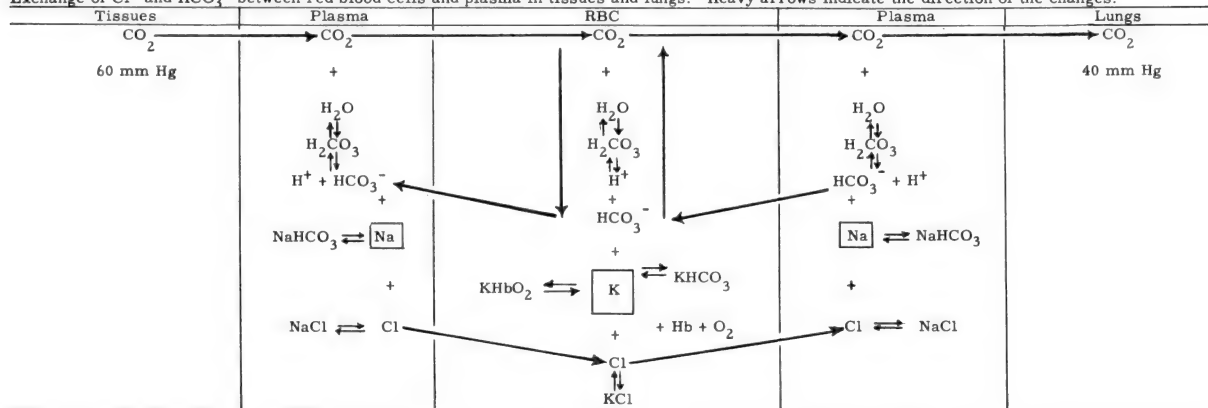
Part I: GENERAL

Values in parentheses are ranges and represent estimate "b" or "c" of the 95% range (cf Introduction).

Animal	Body Temp °C	Sample	Whole Blood				Plasma					
			pH ²	Hemo-globin mM/L ³	Cell Vol-ume %	CO ₂ Comb. Power ⁴ mM/L	CO ₂ Total mM/L	CO ₂ Pressure ⁵ mm Hg	Na ⁺ mEq/L	Cl ⁻ mEq/L	H ₂ O g/L	Pro-tein g/L
1 Man												
2 Birth-10 da	37	C	7.42(7.31-7.53) ^b	10.0			22.7(18-27) ^b	34(27-42) ^b				60
3 1 mo-2 yr	37	V	7.38(7.30-7.46) ^b	10.3			23.6(20-28) ^b	38				
4 6-15 yr, ♂♀	37	V	7.38	7.0			24.2(19-29) ^b	38				
5 16-50 yr, ♂	37	A	7.40(7.33-7.47) ^b	8.2			25(22-28) ^b	38(29-47) ^b				
6 16-50 yr, ♂	37	V	7.38(7.32-7.44) ^b	8.2			27(23-30) ^b	43(35-50) ^b				
7 16-50 yr, ♂	37	A	7.39(7.33-7.45) ^b	9.0			27(25-29) ^b	42(36-47) ^b				
8 16-50 yr, ♂	37	C	7.39(7.33-7.45) ^b	9.4			27	43(35-50) ^b				
9 16-50 yr, ♀	37	V	7.35(7.27-7.43) ^b	9.0			29(24-34) ^b	49	139(133-143) ^c			73
10 16-50 yr, ♀	37	C	7.41(7.35-7.47) ^b	7.9			26	39(34-44) ^b				
11 Over 50 yr, ♂	37	V	7.37(7.31-7.43) ^b	7.9			27(24-31) ^b	44				
12 Over 50 yr, ♂	37	A	7.42(7.32-7.52) ^b	7.7			25	37(29-45) ^b				
13 Over 50 yr, ♀	37	C	7.39(7.32-7.46) ^b	8.8			27	42(33-50) ^b				
14 Adult, ♂	37	A	7.42(7.34-7.50) ^b	7.8			25	36(28-54) ^b				
15 Cat	38.6	M	7.35(7.24-7.40) ^c	9.0	45	25.7	27(25-29) ^b	42(36-47) ^b	138(132-144) ^b	102(97-108) ^b	940	68
16 Anesthetized	38.6	V	7.28(7.18-7.35) ^c	6.8	40	17.0	21.8(19-25) ^c	45(34-52) ^c	153(150-156) ^b	120(117-123) ^b	941	
17 Cow	38.5	A	(7.35-7.50) ^b	7.0	40	21.5						74
18 Dog	38.9	A	7.36(7.31-7.42) ^c	9.0	46	18.6	21.4(17-24) ^c	38	147(140-154) ^b	114(108-119) ^b	941	83
19 Guinea pig	38.6	H(A)	7.35(7.17-7.55) ^c	8.7	42	18.5	22(16-26) ^c	40(19-59) ^c	141(138-144) ^c	104(100-108) ^c	954	47
20 Hamster												
21 Anesthetized	38	H(V)	7.39(7.37-7.44) ^c	8.4	46	26.0	37.3(35-39) ^c	59(54-61) ^c	144(140-151) ^b	106(103-108) ^c	945	
22 Hibernating	5	H(V)	7.44(7.34-7.56) ^c				42.4(35-50) ^c	32(26-42) ^c				
23 Horse	37.8	V	(7.20-7.55) ^c	6.8	33	23.0	28.1(24-32) ^c	47	135	96	931	68
24 Rabbit	39.4	A	7.35(7.21-7.57) ^c	7.2			22.8(13-33) ^c	40(22-51) ^c	140(139-142) ^c	102(99-105) ^c	944	
25 Rat	38.2	A	7.35(7.26-7.44) ^b	9.0	46	19.5	24(20-28) ^b	42	144(135-155) ^b	104(99-112) ^b	946	60
26 Sheep	39.1	V	7.44(7.32-7.54) ^c	7.6	32	20.5	26.2(21-28) ^c	38	153(146-161) ^c	103(98-109) ^c	947	57
27 Chicken	41.7	V	7.54(7.45-7.63) ^c	6.8	32		23(21-26) ^c	26	154(148-161) ^c	117(109-120) ^c	960	36
28 Alligator	5	H(M)	7.74	4.2	25	34.5	36.1	15		110	958	41
29 Chameleon	26	H(M)	7.30(6.87-7.66) ^c	4.3	22		18.8(15-27) ^c	38	144(130-148) ^c	107(83-128) ^c	952	50
30 Iguana, black	26	H(M)	7.26(6.93-7.63) ^c	4.2	28		15.4(10-22) ^c	27	157(139-186) ^c	127(113-133) ^c	958	41
31 Snake, garter	26	H(M)	7.22(7.05-7.42) ^c	3.6	35		14.5(10-22) ^c	28	159(158-163) ^c	133(128-137) ^c	940	68
32 Snake, garter	26	H(M)	7.25(7.12-7.50) ^c		28		6.6(3-16)	27	156(143-169) ^c	130(122-143) ^c		42
33 Carp	20	H(V)	7.39(7.33-7.45) ^c	6.4	31		17.7(14-22) ^c	22	130(126-137) ^c	107(96-121) ^c	957	42
34 Skate	10.4	A	7.82	2.7	20	8.4	3.5	1.3	254(219-289) ^c	255(230-285) ^c	967	27

/1/ A=arterial blood; C=cutaneous; H=heart; M=mixed arterial and venous; V=venous. /2/ "Blood" pH is actually plasma pH. /3/ Assumed concentration of 20 mM hemoglobin per liter red cells. One mM (single Fe-atom structure, molecular weight 16,500) combines with 22.4 ml of O₂, S.T.P., when saturated. /4/ Total CO₂ concentration of oxygenated whole blood at pCO₂ of 40 mm (normal alveolar pCO₂ for many animals) and at body temperature, unless otherwise indicated. /5/ Calculated from pH and total CO₂ of plasma at body temperature by the Henderson-Hasselbalch equation. /6/ Venous blood.

Part II: CHLORIDE-BICARBONATE SHIFT

Exchange of Cl⁻ and HCO₃⁻ between red blood cells and plasma in tissues and lungs. Heavy arrows indicate the direction of the changes.

Part III: ACIDOSIS AND ALKALOSIS

Biochemical characteristics of uncompensated and compensated acidosis and alkalosis. + = increase; - = decrease; N = normal.

Plasma	Normal Values	Acidosis				Alkalosis			
		HCO ₃ ⁻ Deficit		H ₂ CO ₃ Excess		HCO ₃ ⁻ Excess		H ₂ CO ₃ Excess	
		Uncomp.	Comp.	Uncomp.	Comp.	Uncomp.	Comp.	Uncomp.	Comp.
1 HCO ₃ ⁻	26(23-28) mM/liter; 58(51-62) vol %	--	-	+	+	++	+	-	-
2 CO ₂ combining power	30(24-35) mM/liter; 65(53-78) vol %	--	-	+	+	++	+	-	-
3 H ₂ CO ₃	1.3(1.1-1.5) mM/liter; 2.9(2.4-3.3) vol %	-	-	++	+	+	+	--	-
4 pCO ₂	40(35-45) mm Hg	-	-	++	+	+	+	--	-
5 CO ₂ total	28(24-33) mM/liter; 62(53-75) vol %	--	-	++	+	++	+	--	-
6 HCO ₃ ⁻ / H ₂ CO ₃	20	-	N	-	N	+	N	+	N
7 pH	7.4(7.35-7.45)	-	N	-	N	+	N	+	N
8 Urinary acidity and ammonia	<27 ml/kg 0.1 M acid (+NH ₃)/24 hr	+	+	+	+	-	-	-	-

254. BLOOD GASES: MAN

The values from which this table has been synthesized are in many instances derived by calculation from basic assumptions, factors, and constants, and do not have the same validity as measured values. Those for women are in general less well-founded than those for men. A = arterial blood; V = venous blood.

Variable		Whole Blood			ml Gas in 100 ml RBC (In Contact)		Blood Gas Pressure (Tension) mm Hg
		ml Gas in 100 ml Whole Blood	ml Gas in σ 45.0 ml φ 40.0 ml RBC	ml Gas in σ 55.0 ml φ 60.0 ml Plasma	ml Gas in 100 ml RBC	ml Gas in 100 ml Plasma	
1 Oxygen capacity	σ	20.4			45.3		
2	φ	18.0			45.3		
3 Total oxygen	A ¹	20.3	20.1	0.142	44.7	0.258	94
4	V ¹	17.9	17.7	0.155	44.7	0.258	94
5	σ	15.3	15.2	0.060	33.9	0.110	40
6	φ	13.7	13.6	0.068	34.4	0.113	41
7 "Free" oxygen	A	0.285	0.144	0.142	0.319	0.258	94
8	V	0.282	0.126	0.156	0.319	0.258	94
9	σ	0.122	0.061	0.061	0.136	0.110	40
10	φ	0.124	0.055	0.068	0.139	0.113	41
11 Combined oxygen (HbO ₂)	A	20.0	20.0	0	44.4	0	94
12	V	17.6	17.6	0	44.4	0	94
13	σ	15.2	15.2	0	33.6	0	40
14	φ	13.6	13.6	0	34.3	0	41
15 Total carbon dioxide	A ¹	49.0	16.2	32.8	36.0	59.6	41
16	V ¹	48.0	13.6	34.4	34.3	57.0	39
17	σ	53.1	18.0	35.1	40.1	63.8	46
18	φ	51.4	14.9	36.5	37.7	60.4	43
19 "Free" carbon dioxide	A	2.62	1.06	1.56	2.36	2.84	41
20	V	2.53	0.89	1.64	2.25	2.72	39
21	σ	3.00	1.21	1.79	2.69	3.25	46.5
22	φ	2.78	0.96	1.82	2.44	3.01	43
23 Total combined carbon dioxide	A	46.4	15.1	31.2	33.6	56.8	41
24	V	45.5	12.7	32.8	32.1	54.3	39
25	σ	50.1	16.8	33.3	37.4	60.5	46.5
26	φ	48.6	14.0	34.7	35.3	57.4	43
27 Carbamino carbon dioxide	A	2.2	1.7	0.4	3.9	0.8	41
28	V	1.9	1.5	0.5	3.7	0.8	39
29	σ	3.1	2.6	0.5	5.8	0.8	46.5
30	φ	2.7	2.2	0.5	5.5	0.8	43
31 Bicarbonate carbon dioxide	A	44.2	13.4	30.8	29.8	56.0	41
32	V	43.6	11.2	32.3	28.3	53.5	39
33	σ	47.0	14.2	32.8	31.6	59.7	46.5
34	φ	46.0	11.8	34.2	29.8	56.6	43
35 Nitrogen	A & V	0.979	0.494	0.484	1.099	0.881	572
36		0.970	0.437	0.534	1.103	0.884	574

/1/ Difference between arterial and venous values for O₂ and CO₂ can vary, depending on vein from which blood was drawn, the presence of local vascular constriction or dilatation, degree of cold or warmth, or metabolic activity.

256. RESPIRATORY CHARACTERISTICS, ARTERIAL AND VENOUS BLOOD: MAN, ADULT AND NEWBORN

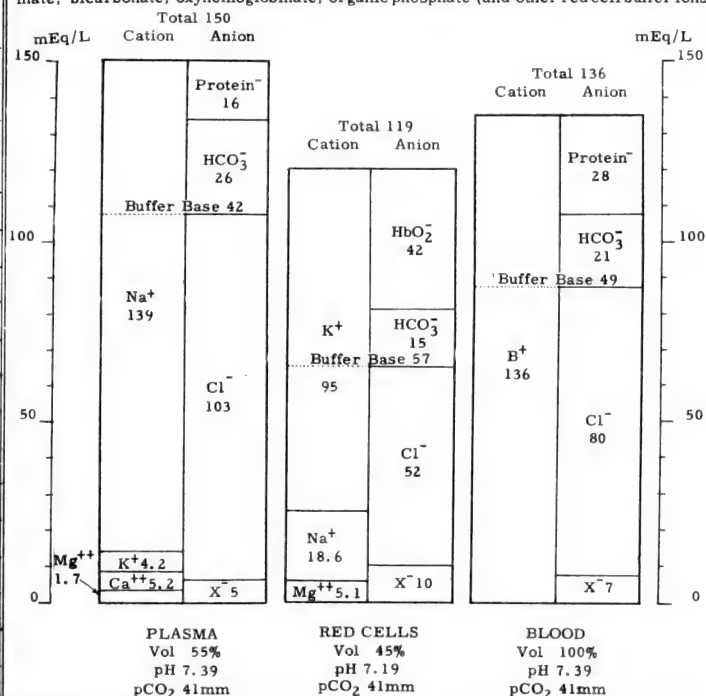
Adult values are averages of means. Ranges in parentheses are estimate "c" and "d", as indicated, of the 95% range (cf Introduction). A = arterial; V = venous. In the newborn (before first breath), where the oxygenated blood goes from the placenta to the fetus via the umbilical vein, A refers to the vena umbilicalis and V to the arteria umbilicalis.

Measurement		Adult ¹		Newborn		Measurement		Adult ¹		Newborn	
1 O ₂ Tension, mm Hg	A	95.2(80.0-104.0) ^c		24.4(13.5-34.0) ^d		9 CO ₂ Tension, mm Hg	A	41.0(35.0-47.0) ^c		44.9(35.0-60.0) ^d	
2	V	39.4(29.5-48.5) ^d		10.4(1.2-19.0) ^d		10	V	43.3(33.0-54.3) ^c		59.2(43.5-68.0) ^d	
3 O ₂ Content, vol %	A	19.4(17.3-22.3) ^c		10.6(5.6-17.9) ^d		11 CO ₂ Content, vol %	A	48.9(42.8-57.1) ^c		40.9(31.2-51.8) ^d	
4	V	15.0(12.6-16.4) ^c		2.9(0.4-8.4) ^d		12	V	51.2(45.2-61.5) ^c		48.0(37.4-55.2) ^d	
5 O ₂ Capacity, vol %	A	20.2(16.8-23.1) ^c		22.2(17.2-26.2) ^d		13 pH	A	7.426(7.37-7.49) ^c		7.32(7.23-7.41) ^d	
6	V	4.6(3.2-6.0) ^{c2}		7.2(2.1-12.5) ^{d3}		14	V	7.40(7.36-7.47) ^c		7.25(7.14-7.37) ^d	
7 O ₂ Saturation, %	A	96.4(90.5-101.0) ^c		47.7(25.7-73.8) ^d							
8	V	73.3(63.0-81.9) ^c		13.9(2.4-37.6) ^d							

/1/ Arterial blood from femoral or brachial artery, mixed venous blood from pulmonary artery. /2/ Arterio-venous O₂ difference. /3/ Venous-arterial O₂ difference.

255. IONIC BALANCE AND BUFFER BASE, ARTERIAL BLOOD, CELLS, AND PLASMA: MAN

Values shown in these diagrams are for adult male, and are mEq per liter of plasma, red cells, and whole blood, respectively. X⁻ = undetermined anion residue. HbO₂ includes other red cell buffer ions, such as organic phosphate. pH of whole blood = plasma pH. pCO₂ = CO₂ tension. B⁺ = mEq total base (Na⁺, K⁺, etc.) on basis of hematocrit values of 45% red cells. Buffer Base = that quantity of total base equivalent in amount (in terms of mEq) to the labile portion of the total anions, i.e., proteinate, bicarbonate, oxyhemoglobinate, organic phosphate (and other red cell buffer ions).

257. H₂CO₃ DISSOCIATION CONSTANTS IN BLOOD, SERUM, AND RBC: MAN, OX, DOG¹

Medium	Temp °C	Dissociation Constant (pK)
1 Serum ²	38	6.11(6.097-6.122) ³
2 Plasma	42	6.067 ⁴ , 6.073 ⁵ , 6.063 ⁶
3	37	6.09 ⁴ , 6.098 ⁵ , 6.088 ⁶
4	31	6.11 ⁴ , 6.116 ⁵ , 6.107 ⁶
5	25	6.12 ⁴ , 6.125 ⁵ , 6.120 ⁶
6 RBC		
7 Reduced	37	5.98
8 Oxidized	37	6.04

/1/ Same values found for all three forms.
/2/ Normal men. /3/ Range. /4/ At pH 7.4.
/5/ At pH 7.1. /6/ At pH 7.6.

258. ATMOSPHERIC CHARACTERISTICS: VARIOUS ALTITUDES

Altitude ft	Temperature			Pressure					O ₂ Part. Press.	Weight	Density		Pressure
	°C	°F	°K	atm	psi	mm Hg	in. Hg	millibars	mm Hg	lb/cu ft	g/ml	Ratio	Ratio
1 0	15.0	59	288.0	1.000	14.67	760.0	29.92	1013.2	159.2	0.07651	1.25x10 ⁻³	1.00	1.00
2 5,000	5.1	41.2	278.1	0.835	12.23	632.3	24.89	842.9	132.5		1.08x10 ⁻³	8.62x10 ⁻¹	8.32x10 ⁻¹
3 10,000	-4.8	23.3	268.2	0.690	10.11	522.9	20.58	697.1	109.5	0.05649	9.22x10 ⁻⁴	7.38x10 ⁻¹	6.88x10 ⁻¹
4 15,000	-14.7	5.5	258.3	0.566	8.29	428.6	16.87	571.4	89.8		7.86x10 ⁻⁴	6.29x10 ⁻¹	5.64x10 ⁻¹
5 20,000	-24.6	-12.3	248.4	0.460	6.76	348.8	13.75	465.0	73.1	0.04075	6.66x10 ⁻⁴	5.33x10 ⁻¹	4.59x10 ⁻¹
6 25,000	-34.5	-30.2	238.5	0.372	5.46	282.0	11.10	375.9	59.1		5.60x10 ⁻⁴	4.48x10 ⁻¹	3.71x10 ⁻¹
7 30,000	-44.4	-48.0	228.6	0.296	4.36	225.7	8.88	300.9	47.3	0.02861	4.67x10 ⁻⁴	3.74x10 ⁻¹	2.97x10 ⁻¹
8 35,000	-54.3	-65.8	218.7	0.236	3.46	178.6	7.03	238.1	37.4		3.87x10 ⁻⁴	3.10x10 ⁻¹	2.35x10 ⁻¹
9 40,000	-55.0	-67.0	218.0	0.191	2.72	140.6	5.54	187.4	29.4	0.01872	3.06x10 ⁻⁴	2.45x10 ⁻¹	1.85x10 ⁻¹
10 50,000	-55.0	-67.0	218.0	0.115	1.69	87.4	3.44	116.5	18.3	0.01161	1.90x10 ⁻⁴	1.52x10 ⁻¹	1.15x10 ⁻¹
11 60,000	-55.0	-67.0	218.0	0.071	1.05	54.1	2.13	72.1	11.3	0.00720	1.18x10 ⁻⁴	9.41x10 ⁻²	7.12x10 ⁻²
12 70,000	-55.0	-67.0	218.0	0.044	0.649	33.6	1.32	44.8	7.0	0.00447	7.30x10 ⁻⁵	5.84x10 ⁻²	4.42x10 ⁻²
13 80,000	-55.0	-67.0	218.0	0.027	0.403	20.8	0.82	27.8	4.3	0.00277	4.52x10 ⁻⁵	3.62x10 ⁻²	2.74x10 ⁻²
14 90,000	-55.0	-67.0	218.0	0.017	0.250	12.9	0.51	17.2	2.7	0.00172	2.80x10 ⁻⁵	2.24x10 ⁻²	1.70x10 ⁻²
15 100,000	-55.0	-67.0	218.0	0.011	0.155	8.0	0.31	10.6	1.7	0.00107	1.74x10 ⁻⁵	1.39x10 ⁻²	1.05x10 ⁻²
16 200,000	33.8	93.0	306.8	3.2x10 ⁻⁴	4.6x10 ⁻³	0.24	9.5x10 ⁻³	0.32	0.05		3.28x10 ⁻⁷	2.63x10 ⁻⁴	3.14x10 ⁻⁴
17 300,000	-2.2	28.0	270.8	7.3x10 ⁻⁶	1.1x10 ⁻⁴	0.0055	2.2x10 ⁻⁴	0.0073	0.00011		8.57x10 ⁻⁹	6.86x10 ⁻⁶	7.23x10 ⁻⁶

259. ARTERIAL BLOOD GASES AT ALTITUDE: MAN

Values in parentheses are estimate "b" of the 95% range (cf Introduction).

Altitude ¹		Oxygen				Carbon Dioxide	
		Tension mm Hg	Content ² ml/100ml	Capacity ^{2,3} ml/100ml	Saturation %	Tension mm Hg	Content ml/100ml
ft	m	mm Hg					
Simulated Ascent in Low-Pressure Chamber ⁴							
1 0	0	760	21.1	21.5	98	41	49
2 5,000	1,524	632	19.6	21.5	91(87-95)	36.5	
3 8,000	2,458	564	19.1	21.5	89(84.5-93.5)	37.4	
4 10,000	3,048	523	18.4	21.5	85.4(79-92)	35.8	
5 12,000	3,658	483	18.3	21.5	84.9(77-92.5)	34.8	
6 14,000	4,267	446	17.0	21.5	79.2(71-87.5)	35.4	
7 16,000	4,877	412	16.4	21.5	76.2(65-87.5)	33.8	
8 18,000	5,486	379	15.3	21.5	71.2(57-85.5)	31.8	
9 20,000	6,096	349	15.2	21.5	70.8(57.5-84)	29.4	
Ascent to Altitudes Necessitating Use of Pure Oxygen ⁴							
10 35,000	10,668	179	19.8	21.5	92(84-100)		
11 37,500	11,430	159	20.2	21.5	94	40.6	46.3
12 39,300	11,979	146	19.1	21.5	88.7	39.4	50.0
13 40,000	12,192	141	18.9	21.5	88.1(81-95)	35(26-44)	42.7(35-50)
14 41,000	12,497	134	18.6	21.5	86.4(85-88)	38.1	44.8
15 42,000	12,802	128	17.8	21.5	83(71-95)	40(36-44)	47.1(45-50)
16 43,000	13,106	122	16.9	21.5	78.5(65-92)		41.5(31-52)
17 44,000	13,411	116	15.5	21.5	72.2(58-86)	33.2	44.9
18 45,000	13,716	111	14.6	21.5	68(53-83)		
Permanent Residents in Mountainous Regions							
19 492	150	746	90	20.7	95.4	41	46
20 7,840	2,390	568	68	21.2(18.5-24)	91.7(86.5-97)	37.8(34-42)	41.1(37-45)
21 10,300	3,140	517	66	21.8(19-25)	91.0(87-95)	36.4(31-42)	39.3(34.5-44)
22 12,238	3,730	479	57	21.9(18.5-25)	87.6(84.5-91.5)		36.0(33-39)
23 14,896	4,540	431	47	23.0(19.5-26.5)	81.4(75.5-87)	34.7(29-40)	33.5(32-35)
24 15,950	4,860	413	46	23.4(20.5-26.5)	80.7(76-85)	33.0(28-38)	34.0(31-37)
25 17,521	5,340	387	43	23.0	76.2	29.3	31.8
Newcomers to Mountainous Regions ⁵							
26 11,319	3,450	496	55	20.5	85	31	41
27 15,421	4,700	429	44	18.7	24.1	29.3	38.3
28 17,521	5,340	387	43	18.6	24.5	27.7	35.0
29 20,145	6,140	347	35	16.3	24.9	24.2	30.2

/1/ U. S. Standard Atmosphere. /2/ Combined oxygen only; does not include physically dissolved oxygen. /3/ Values in lines 1-18 assume a uniform hemoglobin content of 15.8 g/100 ml. /4/ For a period not longer than one hour. /5/ Up to 16 days.

260. HEMOGLOBIN, SEA LEVEL AND ALTITUDE: MAN
Values are for residents unless otherwise indicated.

Country		Place		Altitude		Hb Conc. ¹ g/100ml	Corp. Hb ² μg	Country		Place		Altitude		Hb Conc. ¹ g/100ml	Corp. Hb ² μg
		Ft	m									Ft	m		
1 U. S. A.	Portland, Ore.	<1300	<400	15.8	29.3			10 Switzerland	Zurich			1,640	500	15.0	30.0
2 U. S. A.	New Orleans, La.	<1300	<400	15.9	27.2			11 U. S. A.	Denver			4,920	1,500	16.5	30.4
3 U. S. A.	Omaha, Nebr.	<1300	<400	15.0	32.0			12 So. Africa	Johannesburg			5,900	1,800	14.7	24.5
4 Argentina	Buenos Aires	<1300	<400	14.8	27.9			13 Mexico	Mexico City			7,550	2,300	17.7	32.9
5 Germany	Jena	<1300	<400	16.0	31.6			14 Chile	Ollague ³			12,140	3,700	17.0	30.7
6 Hawaii	Honolulu	<1300	<400	15.1	29.7			15 Peru	Morococha			14,760	4,500	20.8	33.8
7 India	Calcutta	<1300	<400	14.8	27.6			16 Chile	Quilcha			17,390	5,300	22.6	30.7
8 Norway	Oslo	<1300	<400	16.2	29.3			17 Chile	Punta ³			20,000	6,100	18.3	31.7
9 Peru	Lima	<1300	<400	16.0	31.1			18 India	Nanga Parbat ³			22,970	7,000	24.7	30.5

/1/ = g hemoglobin per 100 ml blood. /2/ = μg hemoglobin per RBC. /3/ Sojourners.

261. PHYSIOLOGY AND ALTITUDE: MAN

Part I: ERYTHROCYTE AND HEMOGLOBIN VALUES AT ALTITUDE: MAN

Values in parentheses are ranges, estimate "d" of the 95% range (cf Introduction).

Altitude ft	Exposure Time	RBC millions/cu mm	Altitude ft	Exposure Time	Hemoglobin g/100 ml	Altitude ft	Exposure Time	Hematocrit %
1 Gr. level	Resident	4.93(4.0-5.65)	39 Gr. level	Resident	15.1(13.1-17.4)	75 Gr. level	Resident	48.4(42.0-56.0)
2 1840	Resident	4.75	40 1800	Resident	14.3	76 5000	Resident	♂48.4(43.8-53.6)
3 2200	Resident	5.04	41 5000	Resident	♂16.5(15.0-18.3)	77	Resident	♀43.2(37.1-46.1)
4	Resident	4.65	42	Resident	♀14.5(12.7-15.7)	78 10,000	1 da	50.0(41.0-56.0)
5 5000	Resident	♂5.42(4.83-6.07)	43 5750	Resident	14.7	79	2 da	49.2(44.0-55.0)
6	Resident	♀4.63(4.41-5.0)	44	3 wk	15.6	80	4 da	51.0(45.0-59.0)
7 5200	Resident	6.55	45 6000	Resident	15.0	81	5 da	50.6(47.0-58.0)
8 5750	Resident	5.99(5.12-6.82)	46 7450	Resident	♂17.7(14.4-20.1)	82	6 da	49.1(44.0-54.0)
9	3 wk	5.19	47	Resident	♀15.2(12.8-17.7)	83	7 da	50.3(47.0-55.0)
10 7400	Resident	♂5.39(4.53-6.17)	48 7800	Resident	16.4	84	8 da	49.3(46.0-56.0)
11	Resident	♂5.01(4.27-6.01)	49 9500	Resident	16.9	85	9 da	50.4(42.0-56.0)
12 8650	Resident	5.44	50 10,000	1 da	16.7(12.7-19.6)	86	11 da	54.1(43.0-57.0)
13 9200	1-55 da	5.24(4.72-5.67)	51	2 da	16.0(14.0-18.3)	87	13 da	50.4(45.0-55.0)
14 10,000	1 da	5.34(4.32-6.40)	52	4 da	16.0(13.7-19.5)	88 12,240	Resident	54.1(47.8-65.4)
15	2 da	5.58(5.04-6.11)	53	5 da	16.5(14.6-20.0)	89 12,900	Resident	64.3(50.5-86.0)
16	3 da	5.48(4.34-6.90)	54	6 da	16.5(15.2-18.2)	90 14,900	2 da	50.6
17	4 da	5.60(4.14-6.95)	55	7 da	16.2(14.0-18.1)	91	4 da	50.5
18	5 da	5.70(4.37-6.75)	56	8 da	16.3(15.4-18.3)	92	6 da	52.1
19	6 da	5.60(4.91-6.29)	57	9 da	16.6(15.1-18.7)	93	7-21 da	55.6(50.5-63.0)
20	7 da	5.66(4.97-6.56)	58	11 da	15.6(13.3-17.3)			
21	9 da	5.87(5.22-6.72)	59	12 da	15.7(13.3-17.2)			
22	11 da	5.48(4.07-6.51)	60	13 da	16.0(14.2-18.8)			
23	13 da	5.47(4.44-6.54)	61 10,100	Resident	17.2			
24 10,740	Resident	5.82	62 10,300	Resident	16.7			
25 11,400	3 da	♂6.20	63 11,300	Resident	17.5			
26	3 da	♂5.20	64 12,240	Resident	18.8(16.4-22.1)			
27 12,000	Resident	7.50	65 14,100	Resident	18.1			
28	1-7 da	5.54(4.74-5.92)	66 14,200	Resident	18.9			
29 12,200	Resident	5.67(4.70-6.28)	67 14,800	Resident	19.4(15.7-25.0)			
30 12,300	Resident	6.31	68 14,900	Resident	20.8(18.1-25.4)			
31 14,200	Resident	7.05	69	Arr. ¹	16.9			
32 14,800	Resident	6.46	70	2 da	18.4			
33	7-21 da	6.43	71	4 da	17.7			
34 14,900	Resident	6.66(4.80-10.4)	72	6 da	18.3			
35 15,500	2 hr-11 da	5.84(4.66-6.63)	73	1-3 wk	18.6			
36 17,500	Resident	7.37	74 17,500	Resident	22.9			
37	1-16 da	5.93(4.96-6.89)						
38 20,800	3 hr-6 da	5.77(5.41-6.52)						

/1/ On arrival at altitude.

/1/ U. S. Standard Atmosphere.

Part II: LUNG ALVEOLAR O₂, CO₂ AT ALTITUDE: ACCLIMATIZED MAN

Altitude ¹	Bar. Press. ¹	pCO ₂	pO ₂
m	ft	mm Hg	mm Hg
1 Sea level	Sea level	760	38.0
2 305	1000	733	37.7
3 800	2600	690	37.0
4 1900	6200	610	33.6
5 2370	7780	573	30.7
6 2800	9200	543	34.0
7 3050	10,000	522	30.5
8 3457	11,300	496	31.2
9 3820	12,500	489	30.0
10 4700	15,400	429	28.0
11 5340	17,500	401	25.6
12 6140	20,100	356	21.4
13 6460	21,200	331	17.7
14 6950	22,800	310	15.6

Part III: CERTAIN RESPIRATION AND CIRCULATION CHARACTERISTICS AT SIMULATED ALTITUDES: MAN

Data compiled from tests in a low-pressure chamber in which the inspired oxygen was always 20.9%. Values in parentheses are percentages of ground level values. Ground level altitude = 540 ft above sea level.

Simulated Altitude	Respiration Frequency, breaths/min							Ventilation Volume, l/min						
	Ground Level	10	20	30	40	50	60	Ground Level	10	20	30	40	50	60
1 12,000 ft	13	14	13	14	14	14	14	8.85	9.45	9.48	9.50	9.66	9.61	9.77
[483 mm Hg]	(100)	(107.7)	(100)	(107.7)	(107.7)	(107.7)	(107.7)	(100)	(106.8)	(107.1)	(107.4)	(109.2)	(108.6)	(110.4)
2 16,000 ft	13	12	11	13	12	12	11	8.25	9.32	9.14	9.74	8.79	9.39	10.50
[412 mm Hg]	(100)	(92.2)	(84.6)	(100)	(92.2)	(92.2)	(84.6)	(100)	(113.0)	(110.8)	(118.0)	(106.5)	(113.8)	(127.3)
3 18,000 ft	12	11	12	11	11	12	11	8.42	10.9	11.24	11.06	11.73	10.66	10.83
[379 mm Hg]	(100)	(91.7)	(100)	(91.7)	(91.7)	(100)	(91.7)	(100)	(129.5)	(133.5)	(131.4)	(139.4)	(126.6)	(128.5)
4 20,000 ft	11	11	11	12	13			8.40	12.36	11.76	12.46	13.44		
[349 mm Hg]	(100)	(100)	(100)	(109.1)	(118.2)			(100)	(147.1)	(139.9)	(148.3)	(159.9)		
5 22,000 ft	11	12	14	15				8.64	14.61	15.21	15.31			
[321 mm Hg]	(100)	(109.1)	(127.3)	(136.4)				(100)	(169.0)	(176.0)	(177.1)			

Simulated Altitude	Alveolar O ₂ , [CO ₂], mm Hg							Pulse Rate, beats/min					
	Ground Level	10	20	30	40	50	60	10	20	30	40	50	60
1 12,000 ft	101.0	52.1	51.0	50.4	51.4	50.9	50.7	(113)	(115)	(113)	(106)	(104)	(99)
[483 mm Hg]	[37.6]	[35.4]	[35.1]	[34.9]	[34.5]	[34.3]	[34.0]						
2 16,000 ft	106.1	45.6	44.8	45.4	43.2	44.4	44.2	(111)	(110)	(103)	(103)	(101)	(105)
[412 mm Hg]	[34.9]	[30.8]	[30.0]	[28.6]	[29.4]	[28.2]	[28.0]						
3 18,000 ft	107.1	43.1	41.3	40.1	40.8	39.8	41.1	(107)	(109)	(108)	(111)	(108)	(104)
[379 mm Hg]	[35.0]	[28.4]	[27.3]	[27.0]	[26.2]	[26.2]	[25.1]						
4 20,000 ft	104.8	37.6	36.7	36.4	37.9			(124)	(112)	(117)	(107)		
[349 mm Hg]	[35.5]	[26.6]	[24.4]	[24.4]	[23.4]								
5 22,000 ft	103.3	34.0	32.7	32.0				(131)	(126)	(124)			
[321 mm Hg]	[35.3]	[25.1]	[24.6]	[23.5]									

Part IV: CERTAIN RESPIRATION AND CIRCULATION CHARACTERISTICS AT ALTITUDES: MAN

Values in parentheses are ranges, estimate "d" of the 95% range (cf Introduction).

Altitude ft	Exposure Time min	Respiration Frequency breaths/min	Expiratory Minute Volume ¹ l/min	Stroke Volume ² ml	Work, Left Ventricle g/cm x 10 ⁻⁴
1 610 ³		16.8(9.4-24.2)	6.50(4.14-8.86)	72.6(43.0-102.2)	67.4(31.4-103.4)
2 10,000	5	16.5(9.2-23.8)	6.17(4.55-7.79)	74.3(31.6-117.0)	81.2(32.7-129.7)
3	10	16.3(8.0-24.6)	7.10(5.06-9.14)	76.9(34.3-119.5)	76.4(16.8-136.0)
4 18,000	5	17.9(7.8-28.0)	8.55(4.33-12.77)	82.0(37.6-126.4)	98.1(17.4-178.8)
5	10	18.5(10.0-27.0)	8.06(5.42-10.70)	88.4(45.4-131.4)	105.3(37.6-173.0)
6	15	18.1(10.4-25.8)	8.10(4.92-11.28)	93.9(49.6-138.2)	94.5(32.6-156.3)
7	20	15.6(12.5-18.7)	7.09(3.85-10.33)	99.3(50.9-147.7)	106.9(31.4-182.4)

/1/ Total volume of air expired per minute. /2/ Amount of blood discharged from left ventricle with each contraction. /3/ Ground level.

Part V: PULSE RATE AND SYSTOLIC BLOOD PRESSURE IN CHRONIC HYPOXIA (8660 FEET): MAN

Age yr	Pulse Rate beats/min	Systolic Pressure mm Hg
1 7-10	♂81; ♀102	♂160; ♀150
2 10-20	♂83; ♀91	♂170; ♀180
3 20-30	♂75; ♀83	♂190; ♀200
4 30-40	♂72; ♀80	♂180; ♀140
5 50-60	♂81; ♀89	♂200; ♀220
6 60-70	984	♂180; ♀230

262. ERYTHROCYTE AND PLATELET VALUES: VERTEBRATES

Values in parentheses are ranges and where accompanied by superscript, conform to "b" or "c" estimate of the 95% range (cf Introduction).

Animal	RBC millions/cu mm	Hematocrit ml/100 ml	Reticulocytes % of total RBC	RBC Diameter ¹ (dry film) μ	RBC Volume ² cu μ	Blood Hb Concentration g/100 ml blood	RBC Hb Concentration ³ g/100 ml RBC	RBC Hb Content ⁴ μg	Platelets thousands/cu mm
1 Man, birth ⁵	5.7(4.8-7.1) ^c	56.6	4.35(2.5-6.5) ^c		106.0	21.5(18.0-27.0) ^c	38.0	38.0	227(140-290) ^c
2 1 wk	5.3(4.5-6.4) ^c	52.7	1.12(0.1-4.5) ^c		101.0	19.6(16.2-25.5) ^c	37.2	37.0	235(150-320) ^c
3 2 wk	5.1(4.3-6.0) ^c	49.6	0.67(0.2-1.5) ^c		96.0	18.0(14.5-24.2) ^c	36.3	35.0	247(163-340) ^c
4 3 wk	4.9(4.1-6.0) ^c	46.6	0.63(0.2-1.3) ^c		93.0	16.6(13.2-23.0) ^c	35.6	34.0	267(177-367) ^c
5 4 wk	4.7(3.9-5.9) ^c	44.6	0.73(0.1-1.0) ^c		91.0	15.6(12.0-21.8) ^c	35.0	33.0	280(185-390) ^c
6 3 mo	4.5(3.8-5.8) ^c	38.9	1.2(0.5-3.1) ^c		85.0	13.3(10.8-18.0) ^c	34.2	30.0	315(200-428) ^c
7 5 mo	4.5(3.8-5.3) ^c	36.5	1.66(0.9-2.94) ^c		79.0	12.4(10.2-15.0) ^c	34.0	27.0	338(205-465) ^c
8 7 mo	4.6(3.9-5.3) ^c	36.2	1.38(0.72-2.3) ^c		78.0	12.3(10.0-15.0) ^c	34.0	27.0	340(205-470) ^c
9 9 mo	4.6(4.0-5.4) ^c	35.8	1.12(0.65-1.9) ^c		77.0	12.1(9.8-15.0) ^c	33.8	26.0	345(210-473) ^c
10 11 mo	4.6(4.0-5.5) ^c	35.5	0.97(0.62-1.8) ^c		77.0	11.9(8.4-14.9) ^c	33.5	26.0	345(212-470) ^c
11 3 yr	4.7(3.8-5.4) ^c	35.5			78.0	11.7(9.2-15.5) ^c	33.0	25.0	
12 5 yr	4.7(3.8-5.4) ^c	37.1			80.0	12.6(9.6-15.5) ^c	34.0	27.0	
13 7 yr	4.7(3.8-5.4) ^c	37.9			80.0	12.7(10.0-15.5) ^c	33.5	27.0	
14 9 yr	4.7(3.8-5.4) ^c	38.9			80.0	12.9(10.3-15.5) ^c	33.2	27.0	
15 11 yr	4.8(3.8-5.4) ^c	39.0			80.0	13.0(10.7-15.5) ^c	33.3	27.0	
16 >14 yr, male	5.4(4.6-6.2) ^b	47(40-54) ^b	1.5(0.1-3.8)	7.5(7.2-7.8) ^{b6}	87(70-104) ⁷	15.8(14.0-18.0) ^b	33.5(27-40) ^b	29(25-34) ^b	409(273-545)
17 female	4.8(4.2-5.4) ^b	42(37-47) ^b	1.5(0.1-3.8)		87(74-98) ^b	13.9(11.5-16.0) ^b	33.5(30-40) ^b	29(24-33) ^b	409(273-545)
18 Pregnancy, 6 mo	4.0(3.5-4.8) ^b	37(32-42) ^b			92.0	11.4(10.2-14.0) ^b	31.0	28.5	
19 9 mo	4.2(3.7-5.0) ^b	37.5(33-43) ^b			89.0	12.0(10.8-14.4) ^b	32.0	28.5	
20 labor	4.4(4.0-5.0) ^b	39(34-44) ^b			89.0	12.6(11.2-15.0) ^b	32.0	28.6	
21 Post-partum, 10 da	4.5(4.0-5.0) ^b	40(35-45) ^b			89.0	12.8(11.4-15.4) ^b	32.0	28.4	
22 Buffalo, domestic	6.8	44.3(38-52)		5.5	72.0	13(11.0-15.2)	19.0	29.0	
23 Carp	0.84(0.65-1.13)	31.3(21-40) ^b			311(278-340)	10.5(9.4-12.4) ^b	33.5	72(63-78)	
24 Cat	8.0(6.5-9.5)	40(28-52)	0.2	6(5.0-7.0)	57(51-63)	11.2(7.0-15.5)	28(23-31)	14(12-16)	345(164-500)
25 Chicken	2.8(2.0-3.2)	35.6(24-43.3)		11.2x6.8	127(120-137)	10.3(7.3-12.9)	29(27-30)	36.6(33-41)	
26 Chimpanzee	5.1(3.4-6.0)	41.6(24-51)		7.4	81.4(70-91)	12.3(6.5-15.1)	30.6(29-34)	24.5(20-27)	
27 Cow	8.1(6.1-10.7) ^c	40(33-47) ^b		5.9	50(47-54)	11.5(8.7-14.5) ^b	29.0		684(542-975)
28 Dog	6.3(4.5-8.0)	45.5(38-53)	0.7(0-2.7)	7(6.2-8.0)	66(59-68)	14.8(11.0-18.0)	33(30-35)	23(21-25)	461(188-960) ^c
29 Dogfish	0.073(0.06-0.09)	6.8(5.5-7.6)		23.7x17.0	946(650-1180)	1.4(1.0-1.8)	21(19-24)	201(126-282)	
30 Duck ⁸	2.5(1.8-3.3)	14.8(9-21)	0.2(0.1-0.5)	12.8x6.6		14.8(9-21) ^b	38.1		
31 Eel	2.4			13.3x8.1	149.0	9.3			
32 Frog, bull	0.44	29.3(26.6-32.0)		24.8x15.3	670(625-716)	(10-12)	26.0	177.0	
33 Goat	16.0(13.3-17.9)	33(27.0-34.6)		4.0	19.4	10.5(8.8-11.4)	34(33-36)	6.4	
34 Guinea pig	5.6(4.5-7)	42(37-47)	0.9(0.4-1.8)	7.4(7.0-7.5)	77(71-83)	14.4(11-16.5)	34(33-35)	26(24.5-27.5)	783(525-900)
35 Hagfish	0.14(0.12-0.19)	22.2(19.3-27.6)			1530(1470-1560)	4.6(4.0-5.7)	21.0	318(303-330)	
36 Hamster	6.96(3.96-9.96) ^c	49(39-59) ^c	1.8(1.0-3.4)	5.6(5.4-5.8)	70.0	16(2-30) ^c	32.0	23.0	338(160-516) ^c
37 Horse	9.3(8.21-10.35)	33.4(28-42) ^b		5.5		11.1(8-14) ^b	33.0		335(249-461)
38 Lamprey	0.333			14.3	710.0	5.8			
39 Mackerel	3.9(3.6-4.2)	57.5(56-59)		12.4x8.3	146(140-152)	14.8(14.5-15.2)	26.0	37.5(36-39)	
40 Monkey, rhesus		42(32-52) ^b				12.6(10-16)	30.0		267(155-424)
41 Mouse	9.3(7.7-12.5)	41.5	4.0	6.0	49(48-51)	14.8(10-19)	36(33-39)	16(15.5-16.5)	278(246-339)
42 Pike	1.1(0.4-1.37)	(16-33.0)							
43 Rabbit	5.7(4.5-7.0)	41.5(33-50)	2.2(2-3)	7.5 ⁹ (6.5-7.5)	61(60-68)	11.9(8.0-15.0)	29(27-31)	21(19-23)	533(170-1120) ^c
44 Rat	8.9(7.2-9.6) ^b	46(39-53)	2.9(0.6-4.9)	7.5 ⁹ (6.0-7.5)	61(57-65)	14.8(12-17.5)	32(30-35)	17(15-19)	754(702-796)
45 Sea gull	2.6			13.7x8.1	126.4	10.2			
46 Sea robin	1.93			10.4x7.3	130.0	6.2			
47 Sheep	10.3(9.4-11.1)	31.7(29.9-33.6)		4.8	31(30-32)	10.9(10-11.8)	34.5	11.0	441(284-659)
48 Skate, barn door	0.265			21.9x15.6	727.0	3.6			
49 Snake, garter	1.05(0.71-1.39)	28(19-37)		18.1x10.3	267.0	8.5(5.8-11.3)	31.0	82.0	
50 Stingray	0.30			20.6x14.3	612.0	3.0			
51 Swine	6.4	41.5(30-53) ^b			63.0	13.3(10-16.5) ^b	35.0	22.0	403(296-616)
52 Trout	1.01(0.74-1.5)	27.2(22-36)			314(284-348)	8.5(6.2-11.5)	31.2	75(61-82)	
53 Turkey	2.3	38.0		♂15.5x7.5		11.2	23.5		
54 Turtle, box	0.647	25(21-27) ^b	2.0	9.0x19.0	442.0	7.2(6.1-9.1) ^b	20.6	91.0	

100

/1/ Ranges in parentheses are for diameter only. Values otherwise represent length x width. /2/ Mean corpuscular volume. /3/ Blood hemoglobin concentration x hematocrit. /4/ Blood hemoglobin concentration x RBC. /5/ Erythrocyte and hemoglobin values are higher during first week of life if cord is clamped after placental separation. /6/ In plasma = 8.4(7.4-9.4). /7/ Ordinary range of mean corpuscular volume among individuals, 81-95. /8/ As ducks mature, all hematologic values progressively increase, with the exception of reticulocytes which progressively decrease. /9/ In plasma.

263. LEUKOCYTE VALUES: VERTEBRATES

Values are in thousands/cu mm; in most cases they are also given as per cent of total leukocytes. Ranges are in parentheses. Those on lines 1-18, 20, 22, 24 and 28-31 conform to estimate "d" of the 95% range (cf Introduction). Other values and ranges are approximate averages of highly variable unweighted means and ranges from the literature.

Animal	Leukocytes Total	Neutrophils			Eosinophils	Basophils	Lymphocytes	Monocytes
		Total	Band ¹	Segmented				
1 Man ² , birth	18.1(9.0-30.0)	11.0(6.0-26.0)	1.65	9.4	0.4(0.02-0.85)	0.1(0.0-0.64)	5.5(2.0-11.0)	1.05(0.4-3.1)
%	100	61(40-80)	9.1	52	2.2	0.6	31	5.8
2 12 hr	22.8(13.0-38.0)	15.5(6.0-28.0)	2.33	13.2	0.45(0.02-0.95)	0.1(0.0-0.50)	5.5(2.0-11.0)	1.20(0.4-3.6)
%	100	68(40-80)	10.2	58	2.0	0.4	24	5.3
3 24 hr	18.9(9.4-34.0)	11.5(5.0-21.0)	1.75	9.8	0.45(0.05-1.00)	0.10(0.0-0.30)	5.8(2.0-11.5)	1.10(0.20-3.1)
%	100	61(40-75)	9.2	52	2.4	0.5	31	5.8
4 1 wk	12.0(5.0-21.0)	5.5(1.5-10.0)	0.83	4.7	0.50(0.07-1.10)	0.05(0.0-0.25)	5.0(2.0-17.0)	1.10(0.30-2.7)
%	100	45(25-65)	6.8	39	4.1	0.4	41	9.1
5 2 wk	11.4(5.0-20.0)	4.5(1.0-9.5)	0.63	3.9	0.35(0.07-1.00)	0.05(0.0-0.23)	5.5(2.0-17.0)	1.00(0.20-2.4)
%	100	40	5.5	34	3.1	0.4	4.8	8.8
6 4 wk	10.8(5.0-19.5)	3.8(1.0-9.0)	0.49	3.3	0.30(0.07-0.90)	0.05(0.0-0.20)	6.0(2.5-16.5)	0.70(0.15-2.0)
%	100	35	4.5	30	2.8	0.5	56	6.5
7 2 mo	11.0(5.5-18.0)	3.8(1.0-9.0)	0.49	3.3	0.30(0.07-0.85)	0.05(0.0-0.20)	6.3(3.0-16.0)	0.65(0.13-1.8)
%	100	34	4.4	30	2.7	0.5	57	5.9
8 4 mo	11.5(6.0-17.5)	3.8(1.0-9.0)	0.45	3.3	0.30(0.07-0.80)	0.05(0.0-0.20)	6.8(3.5-14.5)	0.60(0.10-1.5)
%	100	33	3.9	29	2.6	0.4	59	5.2
9 6 mo	11.9(6.0-17.5)	3.8(1.0-8.5)	0.45	3.3	0.30(0.07-0.75)	0.05(0.0-0.20)	7.3(4.0-13.5)	0.58(0.10-1.3)
%	100	32	3.8	28	2.5	0.4	61	4.8
10 8 mo	12.2(6.0-17.5)	3.7(1.0-8.5)	0.41	3.3	0.30(0.07-0.70)	0.05(0.0-0.20)	7.6(4.5-12.5)	0.58(0.08-1.2)
%	100	30	3.3	27	2.5	0.4	62	4.7
11 10 mo	12.0(6.0-17.5)	3.6(1.0-8.5)	0.40	3.2	0.30(0.06-0.70)	0.05(0.0-0.20)	7.5(4.5-11.5)	0.55(0.05-1.2)
%	100	30	3.3	27	2.5	0.4	63	4.6
12 12 mo	11.4(6.0-17.5)	3.5(1.5-8.5)	0.35	3.2	0.30(0.05-0.70)	0.05(0.0-0.20)	7.0(4.0-10.5)	0.55(0.05-1.1)
%	100	31	3.1	28	2.6	0.4	61	4.8
13 2 yr	10.6(6.0-17.0)	3.5(1.5-8.5)	0.32	3.2	0.28(0.04-0.65)	0.05(0.0-0.20)	6.3(3.0-9.5)	0.53(0.05-1.0)
%	100	33	3.0	30	2.6	0.5	59	5.0
14 6 yr	8.5(5.0-14.5)	4.3(1.5-8.0)	0.25(0.0-1.0)	4.0(1.5-7.0)	0.23(0.0-0.65)	0.05(0.0-0.20)	3.5(1.5-7.0)	0.40(0.0-0.8)
%	100	51	3(0.0-10)	48(16-60)	2.7	0.6	42	4.7
15 10 yr	8.1(4.5-13.5)	4.4(1.8-8.0)	0.24(0.0-1.0)	4.2(1.8-7.0)	0.20(0.0-0.60)	0.04(0.0-0.20)	3.1(1.5-6.5)	0.35(0.0-0.8)
%	100	54	3(0.0-10)	51(16-60)	2.4	0.5	38	4.3
16 14 yr	7.9(4.5-13.0)	4.4(1.8-8.0)	0.24(0.0-1.0)	4.2(1.8-7.0)	0.20(0.0-0.50)	0.04(0.0-0.20)	2.9(1.2-5.8)	0.38(0.0-0.8)
%	100	56	3(0.0-10)	53(16-60)	2.5	0.5	37	4.7
17 18 yr	7.7(4.5-12.5)	4.4(1.8-7.7)	0.23	4.2	0.20(0.0-0.45)	0.04(0.0-0.20)	2.7(1.0-5.0)	0.40(0.0-0.8)
%	100	57	3.0	54(25-70)	2.6	0.5	35	5.2
18 21 yr	7.4(4.5-11.0)	4.4(1.8-7.7)	0.22(0.0-0.7)	4.2(1.8-7.0)	0.20(0.0-0.45)	0.04(0.0-0.20)	2.5(1.0-4.8)	0.30(0.0-0.8)
%	100	59	3(0.0-6)	56(37-75)	2.7	0.5	34	4.0
19 Cat	16.0(9.0-24.0)	9.5(5.5-16.5)			0.85(0.2-2.5)	0.02(0.0-0.1)	5.0(2.0-9.0)	0.65(0.05-1.4)
%	100	59.5(44-82)			5.4(2-11)	0.1(0.0-0.5)	31(15-44)	4(0.5-7.0)
20 Cow	(5-12)	(1.2-4.8)			(0.18-1.8)	(0.0-0.1)	(2.7-6.9)	(0.15-1.8)
21 Dog	12.0(8.0-18.0)	8.2(6.0-12.5)			0.6(0.2-2.0)	0.09(0.0-0.30)	2.5(0.9-4.5)	0.65(0.3-1.5)
%	100	68(62-80)			5.1(2-14)	0.7(0.0-2.0)	21(10-28)	5.2(3.0-9.0)
22 Goat	(5-14)	(2.1-3.4)			(0.0-1.1)	(0.0-0.6)	(2.1-11.3)	(0.05-0.60)
23 Guinea pig	10.0(7.0-19.0)	4.2(2.0-7.0) ³			0.4(0.2-1.3)	0.07(0.0-0.30)	4.9(3.0-9.0)	0.43(0.3-2.0)
%	100	42(22-50)			4.0(2-12)	0.7(0.0-2.0)	49(37-64)	4.3(3-13)
24 Horse	(5-11)	(3.0-6.9)			(0.05-0.60)	(0.0-0.1)	(1.2-4.8)	(0.1-1.5)
25 Mouse	8.0(4.0-12.0)	2.0(0.7-4.0)			0.15(0.0-0.5)	0.05(0.0-0.10)	5.5(3.0-8.5)	0.30(0.0-1.3)
%	100	25.5(12-44)			2.0(0.0-5.0)	0.5(0.0-1.0)	68(54-85)	4.0(0.0-1.5)
26 Rabbit	9.0(6.0-13.0)	4.1(2.5-6.0) ³			0.18(0.0-0.4)	0.45(0.15-0.75)	3.5(2.0-5.6)	0.70(0.3-1.3)
%	100	46(36-52)			2.0(0.5-3.5)	5.0(2.0-7.0)	39(30-52)	8.0(4-12)
27 Rat	14.0(5.0-25.0)	3.1(1.1-6.0)			0.3(0.0-0.7)	0.1(0.0-0.20)	10.2(7.0-16.0)	0.30(0.0-0.65)
%	100	29(9-34)			2.2(0.0-6.0)	0.5(0.0-1.5)	73(65-84)	2.3(0.0-5.0)
28 Sheep	(4-10)	(1.0-4.5)			(0.05-0.70)	(0.0-0.20)	(2.5-7.0)	(0.05-0.80)
29 Swine	(7-20)	(2.4-10.0)			(0.05-2.0)	(0.0-0.80)	(3.2-12.0)	(0.05-2.0)
30 Chicken	(16-40)	(4.0-16.0)			(0.2-1.6)	(0.0-24.0)	(8.0-6.0)	(1.0-6.0)
31 Duck						1.0(0.0-4.5)	45.8(13.0-73.5)	4.4(0.5-11.5)

/1/ Includes a small percentage of myelocytes during the first several days after birth. /2/ Values and ranges from birth through 12 months are from fragmentary data. A few polymorphocytes may be found in the blood of healthy infants up to 4 years of age. /3/ Cells classed as "neutrophils" include "pseudoeosinophils," "amphophils" or "heterophils."

264. HEART RATES

Heart rates are widely variable and influenced by such conditions as breed, sex, age, environment, size, temperature and many others. Although temperature is particularly important in determining invertebrate heart rates, it is not specified in many of the literature sources. Ranges are given in parentheses and correspond with estimate "d" of the 95% range (cf Introduction).

Animal	Beats/min	Animal	Beats/min	Animal	Beats/min
VERTEBRATES		VERTEBRATES (continued)		VERTEBRATES (concluded)	
Mammalia		Mammalia (concluded)		Pisces (concluded)	
1 Man (<i>Homo sapiens</i>)		81 Swine (<i>Sus scrofa</i>), newborn	227	153 Eel (<i>Anguilla</i> spp)	(39-68)
2 Embryo, 5 mo	156(150-160)	82 Tapir (<i>Tapirus indicus</i>)	44	154 Eel, marine (<i>Conger conger</i>)	(33-50)
3 Embryo, 6 mo	154(141-155)	83 Tiger (<i>Panthera tigris</i>)	64	155 Goldfish (<i>Carassius auratus</i>)	(36-40)
4 Embryo, 7 mo	149(118-156)	84 Wallaby (<i>Macropus</i> spp)	125	156 Gurnard (<i>Trigla hirundo</i>)	(62-86)
5 Embryo, 8 mo	142(129-152)	85 Weasel (<i>Mustela frenata</i>)	182(172-192)	157 Haddock (<i>Melanogrammus</i> sp)	(30-40)
6 Embryo, 9 mo	146(131-173)	86 Weasel, shorttail (<i>M. erminea</i>)	357(300-420)	158 Perch (<i>Perca fluviatilis</i>)	(52-66)
7 Newborn, premature		87 Whale (<i>Beluga</i> spp)	16(12-23)	159 Pike (<i>Esox lucius</i>)	(30-54)
8 Newborn	134(101-160)			160 Plaice (<i>Pleuronectes platessa</i>)	(54-76)
9 2 yr	108(84-134)	Aves		161 Pogge (<i>Agonus cataphractus</i>)	(81-90)
10 4 yr	103(80-133)	88 Blackbird (<i>Turdus merula</i>)	(390-590)	162 Ray (<i>Tetranarce</i> spp)	(16-50)
11 6 yr	93(72-128)	89 Brambling (<i>Fringilla</i> sp)	(900-920)	163 Rockling (<i>Montella mustela</i>)	(64-82)
12 8 yr	89(72-114)	90 Buzzard (<i>Buteo</i> spp)	300(206-351)	164 Scorpion fish (<i>Scorpaena scrofa</i>)	(11-24)
13 10 yr	87(56-106)	91 Canary (<i>Serinus canarius</i>)	(514-1000)	165 Sculpin (<i>Cottus scorpis</i>)	(55-74)
14 15 yr	83(66-112)	92 Cassowary (<i>Casuarius galeatus</i>)	70	166 Shad, gizzard (<i>Dorosoma</i> sp)	20(5-50)
15 20 yr	71(59-99)	93 Catbird (<i>Dumetella</i> sp)	330(318-354)	167 Shark (<i>Carcharodon carcharias</i>)	(18-30)
16 20-24 yr	74(41-100)	94 Cardinal (<i>Richmondia</i> sp)	(375-800)	168 Shark (<i>Squalus acanthias</i>)	(16-50)
17 25-30 yr	72(52-102)	95 Chaffinch (<i>Fringilla coelebs</i>)	700	169 Skate (<i>Raja</i> spp)	(16-50)
18 30-35 yr	70(58-104)	96 Chickadee (<i>Parus atricapillus</i>)	(480-1000)	170 Stickleback (<i>Gasterosteus</i> sp)	(60-100)
19 35-40 yr	72(56-100)	97 Cowbird (<i>Molothrus</i> sp)	(315-779)	171 Tench (<i>Tinca tinca</i>)	(31-42)
20 40-45 yr	72(50-104)	98 Crane (<i>Arthropoides paradisea</i>)	120	172 Trout (<i>Salmo trutta</i>)	(30-46)
21 45-50 yr	72(49-100)	99 Crow (<i>Corvus cornix</i>)	378(312-492)	173 Wrasse (<i>Labrus mixtus</i>)	(40-81)
22 50-55 yr	72(52-94)	100 Dove (<i>Columba</i> spp)	282(185-300)	Tunicates ²	
23 55-60 yr	75(48-108)	101 Duck (<i>Anas</i> spp)	268(212-317)	174 Sea squirt (<i>Molgula</i> sp)	(43-80)
24 60-65 yr	73(54-100)	102 Falcon (<i>Falco sennchris</i>)	367	175 (Appendicularis sp)	250
25 65-70 yr	75(52-96)	103 Finch (<i>Carduelis elegans</i>)	920(914-925)	176 (Ascidia depressa)	(31-33)
26 70-75 yr	75(54-104)	104 Fowl (<i>Gallus</i> spp)	312(178-458)	177 (A. mentula)	(16-20)
27 75-80 yr	72(50-94)	105 Goose (<i>Anser a. domesticus</i>)	(80-144)	178 (Ciona intestinalis)	(17-32)
28 80 and over	78(63-98)	106 Goshawk (<i>Accipiter gentilis</i>)	347	179 (Clavellina lepardiformis)	(23-50)
29 Recumbent	66(40-100)	107 Greenfinch (<i>Chloris hortensis</i>)	740(703-848)	180 (Cyclosalpa pinnata)	(26-30)
30 Sitting	73(31-110)	108 Gull (<i>Larus canus</i>)	401(360-483)	181 (Perophora annectens)	43
31 Standing	82(54-124)	109 Hawk (<i>Astur palumbarius</i>)	347	182 (Phallusia mammillata)	(9-12)
32 Sleeping	59; 65	110 Hummingbird (<i>Archilochus colubris</i>)	615 ¹	183 (Pyrosoma giganteum)	(38-58)
33 Waking, male	78(61-119)	111 Jackdaw (<i>Corvus monedula</i>)	342(326-358)	184 (Salpa bicaudata)	(13-40)
34 Waking, female	84(67-121)	112 Kestrel (<i>Tinnunculus alaudarius</i>)	367	185 (S. fusiformis)	(41-69)
35 Ass (<i>Equus asinus</i>)	50(40-56)	113 Kingfisher (<i>Alcedo isipida</i>)	440	INVERTEBRATES	
36 Badger (<i>Taxidea taxus</i>)	138(128-144)	114 Kite (<i>Milvus</i> spp)	258	Arthropoda	
37 Bat (<i>Plecotus auritus</i>)	750(100-970)	115 Ostrich (<i>Struthio camelus</i>)	(60-70)	186 Aphid (<i>Aphis</i> sp)	74(66-80)
38 Beaver (<i>Castor canadensis</i>)	140	116 Parrot (<i>Psittacus erithacus</i>)	320	187 Beetle (<i>Chrysopa</i> sp)	(53-63)
39 Camel (<i>Camelus bactrianus</i>)	30(25-32)	117 Penguin (<i>Aptenodytes</i> spp)	240	188 Botfly (<i>Gastrophilus equi</i>), larva	(40-44)
40 Cat (<i>Felis catus</i>)	120(110-140)	118 Pigeon (<i>Columba</i> spp)	170(141-244)	189 Cockroach (<i>Periplaneta</i> sp)	(60-90)
41 Newborn	(168-300)	119 Redstart (<i>Ruticilla phoeniceus</i>)	890	190 Crab (<i>Limulus polyphemus</i>)	20(8-28)
42 Cattle (<i>Bos taurus</i>)	70(40-100)	120 Robin (<i>Turdus migratorius</i>)	570(520-620)	191 Crab (<i>Maia</i> sp)	(25-46)
43 Chipmunk (<i>Eutamias minimus</i>)	684(660-702)	121 Rook (<i>Corvus frugilegus</i>)	380(352-440)	192 Crab, cocoa-nut (<i>Porcellana</i> sp), larva	170
44 Dog (<i>Canis familiaris</i>)	(100-130)	122 Sparrow (<i>Passer domesticus</i>)	804(745-850)	193 Crayfish (<i>Astacus marinus</i>)	50(30-87)
45 Newborn	(160-180)	123 Sparrow, song (<i>Melospiza</i> sp)	(450-1020)	194 Crayfish (<i>Cambarus clarkii</i>)	116(75-136)
46 Dolphin (<i>Delphinus</i> spp)	150	124 Starling (<i>Sturnus vulgaris</i>)	388(375-400)	195 Daphnia (<i>Daphnia pulex</i>)	(140-166)
47 Dormouse (<i>Muscardinus</i> sp)	646(580-780)	125 Stork (<i>Ciconia</i> sp)	161	196 Lobster (<i>Homarus grammurus</i>)	60(50-100)
48 Elephant (<i>Elephas maximus</i>)	35(22-53)	126 Swan (<i>Sthenelides olor</i>)	257	197 Lobster, rock (<i>Palinurus</i> sp)	35(30-50)
49 Ferret (<i>Mustela vison</i>)	231(216-242)	127 Thrasher, brown (<i>Toxostoma</i> sp)	278(270-294)	198 Moth (<i>Cossus cossus</i>)	15
50 Giraffe (<i>Giraffa camelopardalis</i>)	66	128 Titmouse (<i>Parus major</i>)	870	199 Moth (<i>Sphinx ligustri</i>), larva	61(39-82)
51 Goat (<i>Capra hircus</i>)	90(70-135)	129 Towhee (<i>Pipilo erythrophthalmus</i>)	(445-810)	200 Shrimp (<i>Mysis</i> sp)	260(140-320)
52 Newborn	(145-240)	130 Turkey (<i>Meleagris gallopavo</i>)	211(93-330)	201 Shrimp (<i>Lysmata seticaudata</i>)	175(50-200)
53 Guinea pig (<i>Cavia porcellus</i>)	280(260-400)	131 Vulture (<i>Gyps fulvus</i>)	199	202 Silkworm (<i>Bombyx mori</i>), larva	(30-40)
54 Hamster (<i>Cricetus cricetus</i>)	450(300-600)	132 Wren (<i>Troglodytes aedon</i>)	(450-950)	203 Spider (<i>Eperia diadema</i>)	132(130-134)
55 Hedgehog (<i>Erinaceus europaeus</i>)	300(189-320)	Reptilia		Mollusca	
56 Hibernating	(3-15)	133 Adder (<i>Bitis</i> sp)	40	204 Chiton (<i>Cryptochiton</i> sp)	(5-7)
57 Horse (<i>Equus caballus</i>)	44(23-70)	134 Adder (<i>Tropidonotus natrix</i>)	(23-68)	205 Chiton (<i>Ischnochiton</i> sp)	(12-25)
58 Newborn	(100-120)	135 Blindworm (<i>Anguis fragilis</i>)	64	206 Clam (<i>Dreissensia polymorpha</i>)	(30-60)
59 Hyena (<i>Hyaena hyaena</i>)	(55-58)	136 Crocodile (<i>Crocodilus acutus</i>)	(10-70)	207 Clam (<i>Pisidium</i> sp)	(60-75)
60 Lemming (<i>Dicrostonyx rubricatus</i>)	416(348-465)	137 Lizard (<i>Lacerta viridis</i>)	64(60-66)	208 Clam (<i>Mya arenaria</i>)	(5-14)
61 Lion (<i>Panthera leo</i>)	40	138 Ringsnake (<i>Coluber natrix</i>)	(23-41)	209 Cuttlefish (<i>Sepia officinalis</i>)	(18-40)
62 Manatee (<i>Trichechus</i> spp)	(50-60)	139 Tortoise (<i>Testudo</i> spp)	(11-60)	210 Cuttlefish (<i>Loligo</i> spp)	(60-80)
63 Marmot (<i>Marmota marmota</i>)	180(120-206)	140 Turtle (<i>Emys orbicularis</i>)	(6-9)	211 Mussel (<i>Anodonta cygnea</i>)	(2-29)
64 Monkey (<i>Macaca mulatta</i>)	192(165-240)	141 Turtle (<i>Terrapene</i> spp)	(6-70)	212 Mussel (<i>Mytilus edulis</i>)	(15-25)
65 Mouse (<i>Mus musculus</i>)	600(328-780)	Amphibia		213 Octopus (<i>Octopus vulgaris</i>)	(12-59)
66 Mouse, deer (<i>Peromyscus</i> sp)	534(324-858)	142 Frog (<i>Rana pipiens</i>)	(4-50)	214 Oyster (<i>Ostrea edulis</i>)	(25-30)
67 Opossum (<i>Didelphis virginiana</i>)	(120-240)	143 Salamander (<i>Salamandra</i> spp)	(30-40)	215 Sea hare (<i>Aplysia</i> sp)	(8-35)
68 Panther (<i>Felis concolor</i>)	60	144 Toad (<i>Bufo</i> spp)	(40-50)	216 Sea hare (<i>Pterotrachea</i> sp)	67(50-80)
69 Porcupine (<i>Erethizon dorsatus</i>)	(280-320)	Pisces		217 Scallop (<i>Pecten jacobus</i>)	(22-50)
70 Porpoise (<i>Tursiops truncatus</i>)	150	145 Barbel (<i>Barbus fluviatilis</i>)	(35-90)	218 Slug (<i>Ariolimax agrestis</i>)	(20-40)
71 Rabbit (<i>Oryctolagus cuniculus</i>)	205(123-304)	146 Bass (<i>Micropterus salmoides</i>)	20(5-50)	219 Snail (<i>Helix pomatia</i>)	(10-60)
72 Rat (<i>Rattus</i> spp)	328(261-600)	147 Blenny (<i>Zoarces viviparus</i>)	(71-86)	220 Snail (<i>Helix tuberculata</i>)	(40-45)
73 Seal (<i>Phoca vitulina</i>)	100(10-140)	148 Bullhead (<i>Ameiurus</i> sp)	22(5-50)	221 Snail (<i>Valvata piscinalis</i>)	100
74 Sheep (<i>Ovis aries</i>)	75(60-120)	149 Carp (<i>Cyprinus</i> spp)	(40-78)	222 Snail (<i>Natica</i> sp)	(5-7)
75 Shrew (<i>Blarina brevicauda</i>)	699(618-780)	150 Chub (<i>Leuciscus dobula</i>)	18	223 Snail (<i>Bulla</i> sp)	(10-18)
76 Shrew (<i>Sorex cinereus</i>)	782(588-1320)	151 Cod (<i>Gadus morrhua</i>)	(26-40)	224 Snail (<i>Limnaea auricularis</i>)	(42-100)
77 Skunk (<i>Mephitis mephitis</i>)	166(144-192)	152 Dragonet (<i>Callionymus lyra</i>)	(60-84)	225 Snail, land (<i>Helix hortensis</i>)	40
78 Squirrel (<i>Sciurus vulgaris</i>)	354(320-372)			226 Whelk (<i>Sycotypus</i> sp)	(5-8)
79 Squirrel (<i>Citellus</i> spp)	249(96-378)			Miscellaneous	
80 Swine (<i>Sus scrofa</i>)	(55-86)			227 Clamworm (<i>Nereis virens</i>)	8
				228 Earthworm (<i>Lumbricus terrestris</i>)	17(15-20)
				229 Leech (<i>Hirundo medicinalis</i>)	6
				230 Lugworm (<i>Arenicola</i> sp)	7(6-8)

1/ Basal rate. 2/ Chordates, but neither vertebrates nor invertebrates.

265. ELECTROCARDIOGRAPHIC DEFLECTIONS: VERTEBRATES

P wave = 1st wave of the electrocardiogram (EKG) = auricular activation; Q wave = 1st downward wave of ventricular QRS complex = ventricular activation; R wave = 1st upward wave of QRS complex; S wave = 2nd downward wave of QRS complex; T wave = slow final wave of ventricular complex = restitution of the resting state in ventricles.

PART I: AMPLITUDE: MAN

Values are millimeters (1 mm = 0.1 mV). Values in parentheses conform to estimate "d" of the 95% range (cf Introduction).

Lead ¹	Age yr	P Wave mm	Q Wave mm	R Wave mm	S Wave mm	T Wave mm
1 I	0-10	0.8(0.04-1.2)	0.3(0-1.4)	4.8(1.5-12.3)	2.2(0-6.0)	2.7(0.20-5.0)
2	12-16	0.94(0-2.0)	0.99(0-3.0)	6.35(1.0-16.0)	2.07(0-11.0)	2.65(1.0-6.0)
3	Adults	0.55(0-1.1)	0.33(0-1.5)	6.81(1.5-19.4)	1.67(0-5.0)	2.21(1.0-5.5)
4 II	0-10	1.0(0.4-2.0)	0.6(0-2.8)	10.1(4.3-18.2)	1.0(0-4.1)	3.4(0.3-6.3)
5	12-16	1.62(1.0-3.0)	1.18(0-2.5)	14.0(5.0-25.5)	2.25(0-7.0)	3.48(1.1-8.5)
6	Adults	1.25(0.3-2.5)	0.43(0-2.0)	11.99(4.0-22.0)	1.53(0-8.0)	2.97(1.0-6.0)
7 III	0-10	0.5(-0.9 to 2.0)	1.0(0-0.5-7)	7.4(0.2-19.0)	2.0(0-11.0)	0.7(-2.0 to 3.4)
8	12-16	0.73(-0.5 to 2.0)	1.56(0-5.0)	9.03(1.0-26.5)	1.92(0-9.0)	0.89(-1.5 to 3.5)
9	Adults	0.80(-1.0 to 2.0)	0.54(0-2.0)	8.50(1.2-18.0)	1.27(0-13.0)	1.49(-1.3 to 3.0)
10 aVR	0-10	-0.8(-1.0 to -2.0)	2.5(0-11.4)	2.3(0-5.7)	1.2(0-11.0)	-2.8(-6.1 to -0.2)
11	12-16	-1.14(-2.0 to -0.5)	7.90(0-14.0)	1.4(0-3.5)	10.0(0-15.0)	-2.85(-5.0 to 0)
12	Adults	-0.08(-1.5 to -0.1)	2.81(0-7.6)	0.76(0-3.0)	2.56(0-10.5)	-1.66(-3.3 to -0.8)
13 aVL	0-10	0.4(-0.7 to 1.0)	0.02(0-1.0)	2.4(0-2.8-7)	3.5(0-12.8)	1.3(-1.2 to 7.2)
14	12-16	0.28(-1.0 to 1.0)	1.34(0-6.0)	2.59(0-12.0)	3.98(0-20.1)	1.10(-1.0 to 5.0)
15	Adults	0.2(-1.0 to 1.2)	0.21(0-1.5)	1.13(0-7.0)	2.00(0-7.0)	0.05(-1.0 to 1.0)
16 aVF	0-10	0.8(0.5-1.5)	0.8(0-3.1)	8.3(1.8-18.0)	1.6(0-8.0)	2.0(-1.6 to 4.8)
17	12-16	1.18(0-2.0)	1.28(0-3.0)	10.9(3.0-23.0)	1.73(0-4.0)	2.28(1.1-8.0)
18	Adults	0.7(-1.8 to 1.6)	0.29(0-1.2)	6.68(0-13.0)	0.80(0-6.5)	1.46(0.2-2.8)
19 V ₁	0-10	1.0(0-1.9)	0.0(0-0-0)	8.5(1.8-15.7)	12.3(2.4-25.6)	-2.5(-6.8 to 1.7)
20	12-16	0.44(1.1-1.5)	0.0(0-0-0)	5.62(0.5-16.0)	14.5(5.0-46.0)	-1.2(-4.0 to 7.5)
21	Adults	0.6(-0.8 to 1.6)	0.0(0-0-0)	2.3(0-0-7.0)	10.5(2.0-24.0)	1.23(-4.0 to 5.6)
22 V ₂	0-10	1.0(0-1.8)	0.0(0-0-0)	10.8(3.3-23.4)	16.3(4.4-37.8)	-1.5(-8.2 to 5.6)
23	12-16	1.08(1.1-2.0)	0.0(0-0-0)	9.13(2.0-20.0)	23.7(8.0-52.0)	6.0(1.1-13.5)
24	Adults	0.8(0.2-1.6)	0.0(0-0-0)	4.7(0.0-12.0)	13.4(5.0-38.0)	6.22(0.3-11.0)
25 V ₃	0-10	0.9(0-1.7)	0.05(0-0-0.1)	12.0(1.6-34.1)	14.3(1.5-26.9)	-0.2(-6.2 to 10.1)
26	12-16	1.02(0.5-1.5)	0.0(0-0-0)	11.66(2.5-26.0)	12.6(3.0-35.0)	5.6(1.1-13.5)
27	Adults	0.6(0-1.8)	0.0(0-0-0)	8.6(2.0-27.0)	8.8(3.0-21.0)	6.26(0.4-12.0)
28 V ₄	0-10	0.8(0-1.6)	0.2(0-0-2.0)	15.4(4.5-37.8)	11.9(0.0-28.0)	0.7(-2.0 to 1.4)
29	12-16	0.96(0.25-1.5)	0.0(0-0-0.5)	23.8(6.5-51.0)	6.0(0.5-17.0)	7.5(1.1-17.0)
30	Adults	0.6(0.1-2.3)	0.76(0.0-2.0)	13.0(2.0-25.0)	5.4(0.5-14.0)	5.66(0.3-11.0)
31 V ₅	0-10	0.7(0-1.3)	0.7(0-0-3.4)	15.9(6.7-37.5)	6.7(0.0-22.0)	0.6(0.0-1.0)
32	12-16	0.94(0.25-1.0)	1.31(0.0-4.1)	18.1(6.0-34.0)	3.0(0.0-7.0)	5.93(2.0-13.0)
33	Adults	0.06(0-2.4)	0.24(0-0-1.0)	10.7(3.0-21.0)	1.7(0.0-10.0)	4.59(0.2-9.6)
34 V ₆	0-10	0.7(0.2-1.3)	0.8(0-0-3.7)	13.4(1.0-21.5)	4.2(0.0-23.1)	0.6(0.0-1.0)
35	12-16	0.73(0.25-1.0)	1.30(0.0-2.5)	13.8(5.0-20.0)	1.4(0.0-5.0)	3.98(1.0-7.0)
36	Adults	0.06(0-1.4)	0.49(0.0-2.0)	9.2(3.0-19.0)	0.42(0.0-3.0)	2.55(0.2-5.2)

/1/ Leads: I = between right arm (R) and left arm (L); II = between right arm and left leg (F); III = between left arm and left leg; aVR = between point connected to (L) and (F) through large equal resistances and (R); aVL = between point connected to (R) and (F) through large equal resistances and (L); aVF = between point connected to (R) and (L) through large equal resistances and (F); V₁ = between central terminal (point connected to (R), (L), and (F)) through large equal resistances and 4th intercostal space (ICS) at right sternal border; V₂ = central terminal to 4th ICS at left sternal border; V₃ = central terminal to point midway between V₂ and V₄; V₄ = central terminal to 5th ICS at midclavicular line; V₅ = central terminal to anterior axillary line at ht of V₄; V₆ = central terminal to midaxillary line at ht of V₄.

PART II: DURATION: VERTEBRATES

Values are milliseconds and, except where noted, apply to adult animals.

Species	P Wave ¹ msec	P-R Interval ² msec	QRS Interval ³ msec	Q-T _c ^{4,5} msec
1 Man				
2 0-1 da	52(40-68)	104(80-120)	65(40-100)	421
3 1 da-1 wk	49(36-68)	100(80-120)	56(40-80)	402(322-476)
4 1 wk-1 mo	48(40-60)	97(80-160)	55(40-70)	385(345-434)
5 1-3 mo	47(40-64)	100(80-120)	62(50-80)	397(304-500)
6 3-6 mo	52(48-64)	103(80-130)	68(50-80)	392(348-458)
7 6 mo-1 yr	55(40-70)	108(80-140)	65(40-80)	408(350-455)
8 1-3 yr	59(65-88)	115(80-150)	64(40-80)	394(338-435)
9 3-5 yr	67(40-96)	123(100-160)	69(40-96)	402(349-465)
10 5-8 yr	68(40-96)	130(100-180)	70(40-90)	414(350-514)
11 8-12 yr	73(40-100)	137(100-200)	74(50-96)	419(350-536)
12 12-16 yr	78(50-104)	146(100-200)	76(40-100)	408(302-455)
13 Adult ♂	90(70-120)	160(110-210)	83(50-100)	397(337-433)
14 ♀	90(70-120)	160(110-210)	72(50-100)	415(380-456)
15 Bull	80	180(160-200)	50	310(300-320)
16 Cat	40	80(60-110)	30	(330-400)
17 Cow	110(100-120)	225(220-230)	80	350(260-410)
18 Dog	70(60-80)	120(70-150)	45(30-80)	220(200-240)
19 Donkey	80	200	60	(270-360)
20 Elephant	160(120-200)	350(280-410)	150(120-180)	600(590-790)
21 Goat	80	130(120-140)	50	290(260-320)
22 Guinea pig	40	65(60-100)	30(10-50)	(200-430)
23 Hamster		43(40-46)	21(19-23)	
24 Horse	195(170-220)	370(320-420)	100(80-120)	520(440-600)
25 Monkey		71(54-88)	31(20-44)	(330-400)
26 Mouse, white	20	43(39-47)	22(20-24)	320
27 Mule	101(83-143) ^b	259(227-293) ^b	87(80-97) ^b	440(404-469) ^b
28 Rabbit	40(30-50)	60(50-100)	30(15-40)	(280-360)
29 Rat, white	20	42(35-53)	10(8-13)	(170-190)
30 Sheep	38(20-40)	(80-140)	(50-70)	(240-360)
31 Spermophile		48(38-58)	28(26-30)	
32 Swine	(40-70)	130(120-140)	60(40-80)	250(220-280)
33 Whale		300	(90-120)	240
34 Frog	60	(200-400)	80	600
35 Elasmobranch		190(120-260)	50(40-60)	
36 Teleost		250(200-440)	50(40-160)	750(400-1000)

/1/ Duration of P, measured from the beginning to the end of the P wave. /2/ P-R interval measured from the beginning of the P wave to the beginning of the QRS complex and corresponding to the atrio-ventricular conduction. /3/ QRS interval, measured from the beginning to the end of the QRS complex, and corresponding to duration of intraventricular conduction. /4/ Q-T interval, measured from the beginning of the QRS complex to the end of the T wave. /5/ $Q-T_c = \frac{Q-T}{\sqrt{\text{cycle length}}}$

266. CARDIAC OUTPUT UNDER VARYING CONDITIONS: VERTEBRATES

Values in parentheses are ranges and, where accompanied by superscript, conform to estimate "b" of the 95% range (cf Introduction).

	Species	Body Weight kg	Surface Area sq m	Physiological State	Heart Rate beats/min	Stroke Volume ml/beat	Oxygen Consumption L/min	Cardiac Output L/min	Cardiac Index L/sq m/min	Method
1	Man	18.0	0.82	Basal, age 5	96	23.8		2.28	2.78	Wezler - Böger
2		31.2	1.19	Basal, age 10 1/2	90	36.3		3.27	2.75	Wezler - Böger
3		66.0	1.79	Basal, age 16 1/3	60	86.2		5.18	2.90	Wezler - Böger
4		68.5	1.85	Basal, age 25	65	78.4		5.10	2.76	Wezler - Böger
5		70.0	1.83	Basal, age 33 1/3	68	62.8		4.27	2.33	Wezler - Böger
6		72.4	1.85	Basal, age 47	72	55.8		4.02	2.17	Wezler - Böger
7		69.8	1.79	Basal, age 60	80	57.0		4.55	2.54	Wezler - Böger
8		65	1.78 ¹	Sitting			0.285(0.256-0.309)	6.6(4.7-8.0)	3.7	Ind. Fick - CO ₂
9				Standing ²		29.2(21.9-35.2)		2.21(1.61-2.85)		Wezler - Böger
10			1.84	Tilting to 70°			0.248(0.220-0.272)	4.86(3.94-6.20)	2.7(2.0-3.9)	Direct Fick
11				Acute hypoxia, 760 mm Hg	59.8	72.7		4.35		Broemser - Ranke
12				600 mm Hg	66.8	76.0		5.08		Broemser - Ranke
13				376 mm Hg	75.9	81.3		6.17		Broemser - Ranke
14				260 mm Hg	85.7	105.9		9.08		Broemser - Ranke
15				Hemorrhagic shock	113	31	0.154(0.119-0.223)	3.5	2.20(1.38-2.99)	Direct Fick
16				"Vagotonia"	40	42	0.204	1.7		Wezler - Böger
17				"Sympatheticotonia"	106	110	0.327	9.1		Wezler - Böger
18				Bicycle ergometer						
		65	1.78 ¹	102 kg m/min			0.630(0.621-0.638)	8.8	4.91	Ind. Fick - CO ₂
19		68.1 ³	1.81 ⁴	Basal, age 23 1/2 ⁵	63.3(49-80)	54.9(29-72)		3.43(2.0-5.3)	1.90	Broemser - Ranke
20				Basal, 150 kg m/min ⁶	77.5(51-99)	78.0(54-101)		6.08(3.3-8.6)	3.36	Broemser - Ranke
21				300 kg m/min ⁶	86.3(59-113)	88.4(68-119)		7.62(4.6-10.2)	4.21	Broemser - Ranke
22				450 kg m/min ⁶	97.8(69-127)	108.1(77-170)		10.62(5.9-17.9)	5.87	Broemser - Ranke
23		65	1.78 ¹	525 kg m/min			1.369(1.348-1.390)	14.1(13.8-14.4)	8.0	Ind. Fick - CO ₂
24		64	1.75	840 kg m/min			2.08(2.05-2.10)	19.2(19.0-19.4)	11.0	Acetylene
25		75	1.98	1200 kg m/min			2.92(2.83-2.98)	23.9(23.0-25.1)	12.1	Acetylene
26		75	1.98	1680 kg m/min			3.84(3.79-3.94)	33.8(28.9-37.3)	17.1	Acetylene
27				Treadmill, 6 MPH, 0°			2.41(2.120-2.900)	21.6(18.3-27.5)		Ind. Fick - CO ₂
28				7 MPH, 0°			2.657(2.530-3.530)	27.0(22.0-33.0)		Ind. Fick - CO ₂
29	Bass				20		(0.05-0.09) ⁷			Physical
30	Cat	2.5		Anesthetized		2.0-2.4		0.271(0.168-0.352)	1.55(0.36-2.74) ^b	Fick
31		4.1		Basal ⁷	178.8	3.15	0.56			Wetterer
32	Catfish				19	0.12-0.2 ⁸				Physical
33	Chick embryo							(0.3-1.0) ^b		Physical
34	Cow				60	244		14.6		
35	Dog	6.4	0.39 ⁹	Basal ¹⁰			0.057(0.042-0.068)	1.12(0.65-1.57)	2.9	Direct Fick
36		14.4	0.66 ⁹	Anesthetized				1.82(1.14-2.50) ^b	2.8(1.97-4.18)	Stew. NaCl
37		23.9	0.93 ⁹	Anesthetized				2.66(2.00-3.32) ^b	2.9	Stew. NaCl
38		11.8 ¹¹		Basal ¹²	170.5(123.3-226.0)	6.91(4.42-9.74)		1.18(0.80-1.59)		Wetterer
39		16.1	0.71 ⁹	Basal			0.106(0.063-0.184)	2.21(1.20-3.84)	3.1	Direct Fick
40		15	0.68 ⁹	Shivering			0.234(0.232-0.236)	4.49(3.66-5.31)	6.6	Direct Fick
41		21.6	0.87 ⁹	Treadmill, 3 MPH, 0°			0.459(0.393-0.616)	5.30(4.2-7.8)	6.1	Direct Fick
42		21.5	0.87 ⁹	Standing			0.210(0.193-0.238)	3.9(3.6-4.1)	4.5	Direct Fick
43		21.5	0.87 ⁹	Treadmill, 3 MPH, 5°			0.609(0.598-0.620)	5.8(5.7-5.9)	6.7	Direct Fick
44		21.5	0.87 ⁹	5 MPH, 10°			1.402(1.380-1.420)	12.15(12.1-12.2)	14.0	Direct Fick
45	Dogfish				36	(0.4-1.5)		(0.014-0.054)		Physical
46	Ferret				227			0.139(0.082-0.20)		Direct Fick
47	Goat, kid			Basal				(0.13-0.20) ¹³		Cardiometer
48	Goat, mature	23.7	0.91 ¹	Basal			0.176(0.078-0.329)	3.1(1.37-5.60)	3.4	Direct Fick
49	Horse	283	4.30 ¹⁴	Standing			1.364	18.8	4.4	Direct Fick
50		283	4.30 ¹⁴	Treadmill, 47.6 m/min, 0°			2.965	31.4	7.3	Direct Fick
51		342	4.90 ¹⁴	56.9 m/min, 6.5°			4.414(4.315-4.513)	53.1(46.6-59.5)	10.8	Direct Fick
52		342	4.90 ¹⁴	Standing	120	8.8	2.480	24.0	4.9	Direct Fick
53	Monkey, rhesus							1.06		
54	Rabbit, white	3.2	0.21	Anesthetized			0.021(0.014-0.028)	0.35(0.26-0.48)	1.7	Direct Fick
55		4.13 ¹⁵		Basal ¹⁶	214.5(169.5-288.5)	2.48(1.27-3.79)		0.53(0.25-0.75)		Wett. & Broem. - Ran.
56	Rat	0.18	0.03	Anesthetized		1.3-2.0 ¹⁷		0.047(0.015-0.079) ^b	1.6	Direct Fick

/1/ = $0.11 \times W^{2/3}$. /2/ Average of 5 persons standing about 15 minutes. /3/ Range: 57.3-86.5. /4/ Range: 1.65-2.03. /5/ Range: 18-30. /6/ Duration 2 minutes. /7/ Chloral-urethane narcosis. /8/ Gram/200-400 gram weight of fish. /9/ = $0.112 \times W^{2/3}$. /10/ Morphine. /11/ Range: 8-17. /12/ "Pernocton" narcosis. /13/ Expressed as L/kg. /14/ = $0.10 \times W^{2/3}$. /15/ Range: 3.0-5.2. /16/ Urethane narcosis. /17/ Based upon 0.5 ml/kg, animals weighing between 2.5 and 4.0 kg.

Part I: EFFECT OF POTASSIUM ¹				
Heart	mEq per L	mg %	Blood Pressure	Other Systems
Man and Laboratory Animals			(Not in relation to serum concentration)	
Experimental and therapeutic administration: autointoxication in anuria (crush syndrome, renal disease or obstruction); occasionally in traumatic shock and adrenal insufficiency.	14	56		Increased excretion of sodium.
	13			Potential of acetyl choline.
Cardiac arrest.	12	48	No blood pressure changes until failure from I-V block and arrest.	
	11			
Intraventricular block.	10	40		Essential for synthesis of acetylcholine.
	9			Anti-curare at synapses; anti-fatigue in skeletal muscles.
A-V block, P waves disappear.	8	32	Local stimulating effect may produce reflex rise in BP (also EEG changes) with IV injection.	
	7			
S-T depression.	6	24	No influence on EEG until fall in BP.	
	5			
Increase in amplitude of T wave.	4	16		Patients conscious until death and in full possession of faculties.
	3			
Low amplitude or inverted T waves.	2	8		Muscular weakness in animals; familial periodic paralysis in man.
	1			
Congestive heart failure.	0			
Focal necrosis.				
Cushing's syndrome; alkalosis. Administration of desoxycorticosterone acetate necessary.				

/1/ Values, unless otherwise indicated, are serum concentrations.

267. EFFECT OF INORGANIC IONS AND pH ON THE HEART

Part II: EFFECT OF CALCIUM ¹				
Heart	mEq per L	mg %	Blood Pressure	Other Effects
Man				
Therapeutic administration.	50	100		
Hyperparathyroidism (moderate elevation only).	45	90		
Arrest (range 35-65) in mid systole-diastole.	40	80	No blood pressure change until heart failure.	
Second slowing phase in animals escaping ventricular fibrillation (not prevented by atropine).	35	70		
Ventricular fibrillation.	30	60		Antagonism to potassium in heart.
Ventricular fibrillation (?) (digitalis synergy).	25	50		Anti-curare, especially anti-magnesium.
Phase of tachycardia (range 15-40).	20	40		
Phase of slowing A-V delay & block (range 8-30), prevented by atropine.	15	30	Diminished neuro-excitability.	
Shortened R-T ratio.	10	20		
Marked slowing and short arrest.	5	10		
Normal	5	10		
Lengthened R-T ratio hypoparathyroidism.				Increased neuro-excitability, tetany, convulsions.

Part III: EFFECT OF MAGNESIUM ¹				
Heart	mEq per L	mg %	Blood Pressure	Other Effects
Man and Experimental Animals				
Arrest in diastole (with continued artificial respiration).	40	48		Tetanus at 200 P/S; failure of corneal reflexes.
	35	42		Progressive peripheral vasodilation with fall in BP to zero. Flushing, sensation of warmth; increase in skin temperature (made use of in test of circulation velocity).
	30	36		
	25	30		Tetanus at 40 P/S; respiratory failure. Above 20 mEq, life sustained only by artificial respiration. Anesthesia.
Moderate progressive decrease in rate.	20	24		
	15	18		Tetanus at 20 P/S.
Said to prevent extrasystoles in man.	10	12		Curarization: twitches and tendon reflexes fail at range 6-12 mEq.
Progressive lengthening of P-R interval.	5	6		
Normal				Level (not known) Tetany.

Part IV: SUMMARY OF EFFECTS ON HEART: Ca, K, Na, Mg

+ = increased; - = decreased; ± = no effect, or unknown.

Cardiac Property	Calcium		Potassium		Sodium		Magnesium	
	Increase	Decrease	Increase	Decrease	Increase	Decrease	Increase	Decrease
1 Automaticity	-	±	-	±	±	+	-	±
2 Conductivity	±	±	-	±	±	±	-	±
3 Contractility	+	±	±	±	±	-	-	±
4 Excitability	+	-	-	±	±	±	-	±
5 Relaxation	-	±	+	±	±	+	+	±
6 Rhythmicity	+	±	-	±	±	+	-	±

Part V: EFFECT OF pH ON THE HEART: DOG

Similar results are observed in man.

pH		Cardiac Rate	P-R Interval	Depolarization	Repolarization Process		Bazett's (K)
		beats/min	sec	QRS in sec	ST Segment	T Wave	$K = \frac{QT}{\sqrt{RR}}$
Acid ¹							
1	7.4 ²	150	0.09	0.04	-0.5	+1.3	0.35
2	6.2	120	0.13	0.05	-3.5	+3.0	0.35
Alkali ³							
3	7.4 ²	160	0.09	0.04	-0.5	+1.2	0.35
4	8.0	100	0.11	0.04	-3.5	-4.0	0.35

/1/ Decrease in contractility and automaticity; death in cardiac arrest. /2/ Normal. /3/ Death usually from ventricular fibrillation; produces monophasic currents in animals and predisposes to cardiac arrhythmias. /4/ May be prolonged in man due to Ca⁺⁺ depression or low K.

268. VASCULAR AND CAPILLARY PRESSURES

Part I: VASCULAR PRESSURES: MAN

Chamber or Vessel	Systolic mm Hg	Diastolic mm Hg	Mean mm Hg
1 Small veins ¹			18
2 Medium veins ²			4-7
3 Venae cavae ³			5 to 5
4 Right atrium ³	1-5	0-2	1-3
5 Right ventricle ³	20-30	0-4	
6 Pulmonary artery ³	20-30	8-12	15-18
7 Pulmonary capillary ³			8-10
8 Left atrium ⁴	8-12	5-9	8-10
9 Left ventricle ⁵	90-130	2-8	
10 Aorta	90-130	60-90	70-115

/1/ From animal and human data. /2/ Direct measurement.
/3/ Right heart catheterization. /4/ Transthoracic needle puncture. /5/ Direct measurement, open chest.

Part III: RELATIONSHIP OF CENTRAL AND PERIPHERAL ARTERY PRESSURES: MAN

Values are expressed as percentage of pressure of aorta or sub-clavian near the aorta. Values are means.

Condition and Measurement	Artery		
	Brachial	Radial	Femoral
1 Supine, at rest			
2 Systolic	109	112	110
3 Diastolic	96	93	94
4 Mean	98	94	96
5 Supine, during exercise			
6 Systolic	111	113	101
7 Diastolic	97	93	95
8 Mean	97	93	97
9 70° Head-up tilt			
10 Systolic	111	115	123
11 Diastolic	98	95	98
12 Mean	99	98	100

Part II: CAPILLARY BLOOD PRESSURE: VERTEBRATES

Values in parentheses are estimate "d" of the 95% range (cf Introduction). A = arterial; V = venous.

Animal	Region	Pressure cm H ₂ O
1 Man	Nail bed of finger.	A 43.5(28.6-65.0) ¹
2		V 16.5(8.0-24.5) ¹
3	Skin, hyperemia.	A 66.0(71.0-93.0)
4		V (54.5-66.5)
5	Skin, hypertensive.	A 48.5(10.1-95.1)
6		V 30.8(12.8-58.0)
7 Guinea pig ²	Mesentery, veronal ether anesthesia.	A 38.5(31.0-49.0)
8		V 17.0(13.0-19.5)
9 Rat ²	Mesentery.	A 30.0(22.0-34.0)
10		V 17.0(15.0-20.0)
11	Mesentery.	A 14.4(5.0-22.0) ³
12		V 10.1(6.7-18.0) ³
13	Muscle, normal, urethane.	A 14.9(11.0-18.0)
14		V 9.5(7.0-12.7)
15	Muscle, hyperemia.	A 20.1(17.0-26.0)
16		V 16.0(12.0-17.5)
17	Web, normal, urethane.	A 13.9(10.0-19.0)
18		V 9.6(8.5-13.0)
19	Web, normal, curare.	A 14.5(0.0-20.5)
20		V 10.0(8.5-15.5)
21	Web, hyperemia.	A 19.5(14.0-26.5)
22		V 16.5(15.0-17.5)

/1/ Varies directly with venous pressure as affected by hydrostatic pressure or venous obstruction. Varies directly with arteriolar vasodilatation as produced by emotion, heat, or trauma. Varies inversely with arteriolar vasoconstriction as produced by emotion or cold. Varies minimally in a single capillary with time and also from capillary to capillary. /2/ Decerebrate. /3/ Pithed.

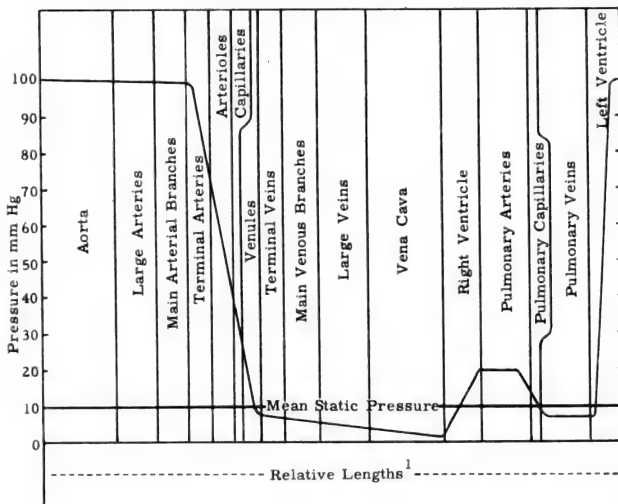
269. PULSE CHARACTERISTICS AND CONFIGURATIONS

Part I: PULSE WAVE VELOCITY FROM CENTRAL TO PERIPHERAL RECORDING SITE: MAN

Recording Site	Velocity M/sec	Recording Site	Velocity M/sec
1 Aorta to radial artery	8.8(6.6-13.8)	3 Aorta to femoral artery	6.3(4.7-10.4)
2 Aorta to brachial artery	7.2(5.4-8.5)	4 Brachial artery to radial artery	12.5(9.3-22.5)

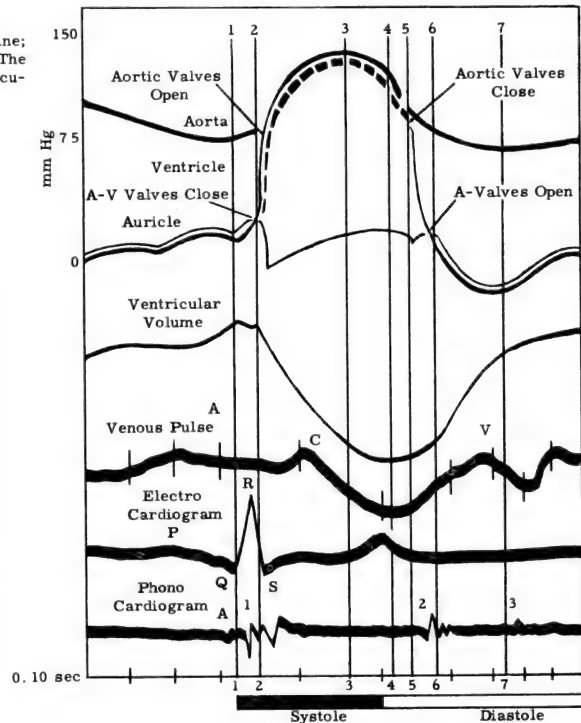
Part II: MEAN BLOOD PRESSURE AND VASCULAR INTERRELATIONS: DOG (SCHEMATIC)

Reference plane is 5 cm anterior to the dorsal surface with the animal supine; ranges are averages of those in the anesthetized dog during expiratory rest. The horizontal line at the level of 10 mm Hg is the pressure at each point during circulation arrest (mean static pressure).



/1/ Arterioles, capillaries and venules should be shorter than indicated.

Part III: CARDIAC CYCLE INTERRELATIONS



270. ARTERIAL BLOOD PRESSURE: MAN

Values are mm Hg. Ranges in parentheses are estimates of the 95% range, those on Lines 1-13 estimate "b," and those on Lines 14-26 estimate "a" (cf Introduction).

Age yr	Male		Female		Age yr	Male		Female	
	Systolic	Diastolic	Systolic	Diastolic		Systolic	Diastolic	Systolic	Diastolic
1 Birth	74	38			14 16	118(95-142)	73(53-93)	116(92-140)	72(54-91)
2 4	89(78-100)	60(46-74)	89(76-102)	60(47-73)	15 17	121(96-146)	74(56-93)	116(93-139)	72(54-90)
3 5	92(80-104)	62(47-77)	92(79-105)	62(49-75)	16 18	120(96-143)	74(55-94)	116(94-139)	72(55-89)
4 6	94(81-107)	64(49-79)	94(80-108)	64(50-78)	17 19	122(92-151)	75(54-95)	115(92-138)	71(54-89)
5 7	97(84-110)	65(50-80)	97(83-111)	66(51-81)	18 20-24	123(96-150)	76(57-96)	116(93-139)	72(53-91)
6 8	100(87-113)	67(53-81)	100(86-114)	64(50-78)	19 25-29	125(100-150)	78(60-95)	117(94-139)	74(56-92)
7 9	101(88-114)	68(55-81)	101(87-115)	69(55-83)	20 30-34	126(99-153)	79(60-98)	120(92-147)	75(54-96)
8 10	103(90-116)	69(57-81)	103(89-117)	70(57-83)	21 35-39	127(99-155)	80(60-101)	124(97-151)	78(58-98)
9 11	104(91-117)	70(59-81)	104(90-118)	71(58-84)	22 40-44	129(100-159)	81(63-100)	127(94-161)	80(59-100)
10 12	106(93-119)	71(61-81)	106(92-120)	72(58-86)	23 45-49	130(97-163)	82(61-103)	131(92-169)	82(59-104)
11 13	108(95-121)	72(62-82)	108(95-121)	73(58-88)	24 50-54	135(97-172)	83(61-106)	137(96-179)	84(59-108)
12 14	110(97-123)	73(63-83)	110(97-123)	74(57-74)	25 55-59	138(101-175)	84(62-106)	139(97-180)	84(61-106)
13 15	112(98-126)	75(64-86)	112(98-126)	76(59-95)	26 60-64	142(100-183)	85(60-109)	144(100-188)	85(60-110)

271. ARTERIAL BLOOD PRESSURE: ANIMALS OTHER THAN MAN

Values are mm Hg. Ranges in parentheses are estimate "d" of the 95% range (cf Introduction).

Species	Systolic	Diastolic	Species	Systolic	Diastolic	Species	Systolic	Diastolic
VERTEBRATES			VERTEBRATES (continued)			VERTEBRATES (concluded)		
Mammals			Birds			Amphibians and Reptiles (concluded)		
1 Bat ¹	50 ²		27 Buzzard	171 ²		52 Toad	48 ²	
2 Cat ²	155	100	28 Canary ¹	220(200-250)	154(150-160)	53 Turtle ³	44(38-55)	37(28-47)
3 Cat, birth	(25-30)		29 Crow	(147-151) ²		Fish		
4 Cattle ³	134(124-166)	88(80-102)	30 Duck	162 ²		54 Barbel		42 ²
5 Cattle, young	130(110-140) ²		31 Falcon	103 ²		55 Bass, large mouth	50	40
6 Dog ³	148(108-189)	100(75-122)	32 Fowl ³	120		56 Bullhead	22	13
7 Dog, birth	50		33 Goose	162(129-176) ²		57 Carp ¹	43(40-45)	
8 Goat ³	120(112-126)	84(76-90)	34 Gull	179 ²		58 Catfish	37	23
9 Guinea pig	(81-90) ²		35 Hawk	178 ²		59 Dogfish	32(30-37)	28
10 Hamster ¹	(90-100) ²		36 Jackdaw	119 ²		60 Eel		(65-70) ²
11 Horse ¹	169(115-188)		37 Kite	194 ²		61 Pike		(35-84) ²
12 Horse, young	80	50	38 Pigeon ³	135(120-140)	105(100-115)	62 Ray	16	7
13 Horse, gelding ³	98(90-104)	(57-71)	39 Red-hawk	103 ²		63 Salmon		75(47-120)
14 Horse, stallion	(70-98)	(40-58)	40 Robin	118(110-125)	80	64 Sand-shark	32	
15 Horse, mare	(86-98)	(53-65)	41 Rook	115 ²		65 Shad, gizzard	48	38
16 Jackass	(90-104)	(54-60)	42 Sparrow ¹	180	140	66 Shark		(30-37) ²
17 Mouse ³	147(133-160)	106(102-110)	43 Sparrow, fledgling ¹	(115-130)		67 Skate	20	
18 Opossum	(120-135) ²		44 Starling ¹	180(150-210)	130(100-160)	68 Torpedo	17(16-18)	10
19 Rabbit ³	110(95-130)	80(60-90)	45 Stork	161 ²		INVERTEBRATES		
20 Rabbit, birth	35		46 Turkey	193 ²		69 Crab	4	
21 Rat	116(88-130)	90(60-100)	47 Vulture	171 ²		70 Earthworm		9.3 ²
22 Rat, 20 da embryo	12 ²		Amphibians and Reptiles ⁴			71 Lobster	10	
23 Seal	(130-140) ²		48 Bull-frog	(26-34)	(12-18)	72 Mussel	3	
24 Sheep	114(90-140)	68(64-76)	49 Crocodile	(30-50) ²		73 Octopus	60	
25 Sheep, 106 da embryo ³	37 ²		50 Frog ³	43(36-56)	31(24-44)	74 Sea-hare	(20-40)	
26 Swine	169(144-185)	108(98-120)	51 Snake, ring	89 ²		75 Squid	(25-80)	

/1/ Anesthetized. /2/ Mean pressure. /3/ Unanesthetized. /4/ Values change with body temperature, rising with raised temperature.

272. PULMONARY CIRCULATION DYNAMICS: MAN AND DOG

Ranges in parentheses are estimate "d" of the 95% range (cf Introduction).

Condition		Pulmonary Pressure, mm Hg ¹				Pulmonary Vascular Gradient mm Hg	Pulmonary Blood Flow L/min	Pulmonary Vascular Resistance (dyne sec)/(cm x 10 ⁵)
		Arterial			Venous ²			
		Systolic	Diastolic	Mean				
Man								
1	Resting	(23-25) ³	(9-14) ³	(14-18) ³	(7-9)	(6-9)	(5.4-7.4) ³	(67-238) ^{3, 4)}
2	Exercise, supine			(15 ³ -21)	10	11	(9.6-10.4) ³	(90-115) ^{3, 4)}
3	Exercise, standing ³	26	9	16			12	76 ⁴
4	Hypoxia	26 ³	12 ³	(18 ³ -20)	(7-8 ³)	(10 ³ -13)	(5.5-8.0 ³)	(119 ³ -189)
5	Saline infusion ³			23	16	7	6.7	84
6	Epinephrine ³			19	7	12	7.9	121
7	Norepinephrine	28	11	21	15	6	4.5	118
8	Tetraethylammonium chloride			15	10	5	4.7	85
Dog								
9	Resting ⁵			(17-18)	(4-10)	(8-13)	(2.3-3.2)	(285-325)
10	Hypoxia, moderate ⁵			(22-26)	(4-8) ⁶	(14-22)	(2.4-3.8)	(463-467)
11	Hypoxia, severe ⁵			26	9 ⁶	17	8.1	167

/1/ Zero point = 10 cm anterior to back in man; = back in dog. /2/ Pulmonary "capillary" mean pressure used except where indicated. /3/ Pressure approximately corrected to 10 cm zero point. /4/ Total pulmonary resistance, utilizing pulmonary arterial mean minus pulmonary "capillary" mean as pressure gradient. /5/ Anesthetized. /6/ Pulmonary venous or left atrial mean pressure.

273. BLOOD FLOW, TISSUES AND ORGANS: MAMMALS

Values in parentheses are ranges and, where accompanied by superscript, conform to the "b" or "c" estimate of the 95% range (cf Introduction).

Species	Body Wt kg	Tissue or Organ	Physiological State	Tissue Weight		Blood Flow			% of Cardiac Output ⁵
				kg	% body wt	ml/100g tissue per min ^{1,2}	ml/total tissue per min ^{2,3}	ml/sq m/min ^{2,4}	
1 Man	70	Total body, arterial (systemic circulation or cardiac output)	Basal	68.8	98.3	7.5(5.7-8.3)	5200	3000	100
2			Exercise			20.1	13,840	8000	100
3			Oligemic shock			4.5	3114	1800	100
4		Lungs (pulmonary circ.)	Basal	1.2	1.7	433(333-485)	5200	3000	100
5			Exercise			1153	13,840	8000	100
6			Oligemic shock			259	3114	1800	100
7		Adrenals	Basal	0.011	0.02	590	65	38	1.2
8		Brain	Basal	1.35	1.93	54(40-71)	729(540-959)		14.0
9			Inhalation 5-7% CO ₂			93(65-141)			
10			85-100% O ₂			45(34-55)			
11			10% O ₂			73(39-107)			
12			Anesthesia, thiopental			61(33-117)	432(324-513)		
13			Oligemic shock			32(24-38)			
14			Sleep			65(48-85)			
15			Supine			64.7(50-103)			
16			Position change						
17			Supine			67.0(52-97)			
18			65° (head up)			53.1(40-81)			
19			Position change						
20			Supine (40°-65°)			65.1(52-97)			
21			Erect			51.6(40-81)			
22			L-Norepinephrine			61(42-83)			
23			L-Epinephrine			66(40-98)			
24			USP Epinephrine			71(42-97)			
25			Age, <45 yr			52(40-63)			
26			>45 yr			46(30-64)			
27		Heart (coronary circ.)	Basal	0.3	0.43	70(50-75)	210(150-225)	121	4.0
28			Exercise			576	1730	1000	12.5
29			Oligemic shock			86.5	259	150	8.0
30		Kidney	Basal	0.16	0.23	750(400-900)	1200(1000-1500)	695	23.0
31			Exercise ⁶			415	1245	650	8.0
32			Oligemic shock ⁶			28.8	86.5	50	3.0
33		Muscle	Basal	28.0	40.0	3.0(2.3-6.5)	850(500-1820)	491	16.3
34			Exercise			19.7	6920	4000	50.0
35			Oligemic shock			1.97	692	400	22.0
36		Liver, hepatic ⁷	Basal	1.5	2.14	20.0	300	173	5.8
37		portal ⁷				80.0	1200	695	23.1
38		Splanchnic flow ⁸	Basal	1.843	2.63		1470	850	28.2
39			Exercise				1038	600	7.5
40			Oligemic shock				605	350	19.4
41		Extremities							
42		Hand ⁹	Basal, 21°C ¹⁰			3.5(1.2-5.3) ^c			
43			24°C ¹¹			5.9(2.7-9.6) ^c			
44			25°C ¹⁰			9.3(5.1-13.5) ^b			
45			21-24°C ¹²			2.1(0.5-6.4) ^c			
46		Forearm	Basal, 15-20°C ¹⁰			9.3(5.8-16.5) ^c			
47			15-20°C ¹³			2.3(1.2-3.0) ^c			
48			15-20°C ¹¹			2.7(1.9-3.8) ^c			
49			18.5°C ¹²			4.2(1.5-7.0)			
50			25-27°C ¹⁴			3.1(2.6-3.6) ^b			
51			27-29°C ¹²			4.5(2.8-6.3) ^c			
52		Calf	Basal, 25°C ¹⁰			4.9(1.7-7.3) ^c			
53		Foot	Basal, 21°C ¹⁰			1.4(0.4-2.4) ^b			
54			24-26.5°C ¹⁰			2.0(0.5-4.4) ^c			
55			Comfortable ¹²			3.9(1.4-7.8) ^c			
56		Finger				(15-40)			
57		Skin & subcutaneous	Basal	18.0 ¹⁵	25.71	1.4(1.2-1.8)	260(220-330)	150	5.0
58			Exercise			4.61	692	400	5.0
59			Oligemic shock			0.57	86.5	50	3.0
60		Thyroid	Basal	0.03	0.04	550	165	96	3.2
61	Monkey	Brain	Anesthesia, barbiturate			47(33-74)			
62			Hemorrhagic shock			24(13-30)			
63			Anesthesia, thiopental			24(14-26)			
64	Cat	Liver	Anesthesia			(33-48)			
65	Rat	Liver	Basal ¹⁶			79(75-92)			
66	Dog	Heart	Basal	0.054 ¹⁷		133(79-220)	70.1(52-103)		
67		Liver	Basal	0.53		82(46-112)	387(216-612)		
68		Hind leg	Basal				55(35-75)		

/1/ = $\frac{(\text{ml/sq m/min} \times 1.73)}{\text{organ wt}} \times \frac{1}{10}$. /2/ Body surface 70 kg man = 1.73 sq m. /3/ = (ml/sq m/min) x 1.73. /4/ = $\frac{(\text{ml/100g tissue/min}) \times (0.1 \text{ organ wt})}{1.73}$

/5/ = Cardiac output. /6/ Values based on organ weight of 0.3 kg. /7/ Calculated from relative hepatic artery flow and portal vein flow as measured in dog. /8/ = portal drained viscera, including intestines, pancreas, spleen, stomach. /9/ Values for extremity flows are ml/min/100 ml segment. Water plethysmography, unless otherwise noted. /10/ Bath temp. 32°C. /11/ Bath temp. 35°C. /12/ Air plethysmography. /13/ Bath temp. 33°C. /14/ Stewart dye principle. /15/ Skin, 4 kg; subcutaneous, 14 kg. /16/ Thermo-electric. /17/ Left ventricle alone.

274. CAPILLARY VASCULARITY, SKELETAL AND CARDIAC MUSCLE: VERTEBRATES

"Capillary" counts from injected cross-section may not exclude other minute vessels (e.g., arterioles, venules). By statistical estimation, numbers of arterioles per capillary per venules = 1/39/2.7 in membranous hamster cheek pouch in vivo; endothelial surface areas = 10/60/30; capacities = 21/18/61. By camera lucida drawings, endothelial surface areas = 21/25/54; capacities = 22/4/74.

Part I: SKELETAL MUSCLE

A = asphyxiated; R = resting; T = trained; U = untrained; V = vasodilated; W = working.

Animal	Muscle		Capillaries per sq mm Cross-section ^{1, 2}	Capillaries per Fiber	Capillary Diameter ³ μ	Capillary Capacity ^{2, 4, 5} cu mm/cu mm	Capillary Surface Area ^{2, 5, 6} sq mm/cu mm
1 Cat	Gastrocnemius	V	2341		6.0	0.066	44.1
2	Rectus femoris	V	2474		6.0	0.070	46.6
3	Tibialis anterior	V	2214		6.0	0.063	41.7
4 Dog, adult	Semimembranosus	R	3240	0.6	7.1	0.128	72.3
5		V	5900	1.6	7.1	0.234	131.6
6		V	2630		7.2	0.107	59.5
7	Gracilis	R	1050	0.6	7.1	0.042	23.4
8		W ⁷	2010	1.2	7.1	0.080	44.8
9		V	2580		7.1	0.102	57.5
10 Dog, puppy	Gracilis	R	1690	0.7	7.1	0.067	37.7
11 Guinea pig	Abdominal wall	R	85		3.0	0.001	0.8
12		R	270		3.8	0.003	3.2
13		V	1400		4.6	0.023	20.2
14	Diaphragm	W ⁸	2570		5.0	0.050	40.4
15		W ⁸ V	3000		8.0	0.151	75.4
16	Gastrocnemius	R	1136		7.5	0.050	26.8
17		U	1378		7.5	0.061	32.5
18		T	1924		7.5	0.085	45.3
19		W ⁷	2000		7.5	0.088	47.1
20		A	2600		7.5	0.115	61.3
21		V	2614		7.5	0.115	61.6
22 Mouse	Gastrocnemius	R	3060		6.6	0.105	63.4
23		W ⁷	3600		6.6	0.123	74.6
24		A	4650		6.6	0.159	96.4
25	Masseter	W ⁷	4393		6.6	0.150	91.1
26		W ⁷ V	5100		6.6	0.174	105.7
27		A	6800		6.6	0.233	141.0
28 Rabbit	Adductor magnus (white)	V	1550	0.7	2.5	0.008	12.3
29	Gastrocnemius	V	1344	1.6	1.8 ⁹	0.004	7.5
30	Gluteal	U		0.5	7.5		
31		T		1.2	7.5		
32	Semitendinosus (red)	V	790	1.2	5.2	0.017	13.0
33		V	1198	3.1	2.3 ⁹	0.005	8.8
34	Rectus femoris	V	1475	1.2	1.6 ⁹	0.003	7.4
35 Rat	Rectus femoris	V	3573		7.5	0.158	84.2
36	Tibialis anterior	V	3402		7.5	0.150	80.2
37 Frog (Rana	Gastrocnemius	V	382	2.6	9.8	0.029	11.8
38 temporaria)	Gracilis	V	406	1.9	9.7	0.030	12.4
39	Obliquus oculi inferior	V	393	0.2	15.0	0.069	18.5
40	Sartorius	R	90		4.4	0.001	1.2
41		W ⁷	325		6.8	0.012	7.0
42		V	400		15.0	0.071	19.0
43		V	426	1.8	8.6	0.025	11.5
44	Submaxillary	V	652	0.7	11.1	0.063	22.7
45 Trout	Eyeball muscle	W ⁸	276		10.6	0.024	9.2
46	Parietal	R	123		9.8	0.009	3.8
47	Rectus lateralis	W ⁸	400		8.3	0.022	10.4

/1/ Differences in counts during rest, work and vasodilation are now attributed to precapillary sphincter action. /2/ Counts are averages. Assumed capillary length = 1 mm. Actual capillary length < 0.5 mm. /3/ Based on RBC diameter, excluding Items 11-15, 37-38, 40-41, 43-47. /4/ Capillary capacities determined by pressure injection are maximal, and differ from capacities (all vessels) by isotope and spectrophotometric methods, which may be minimal and indicate effective in vivo capacities. E.g., vascular capacities (cu mm/cu mm), assuming that muscle density = 1.0: skeletal muscle of cat, 0.027; dog, 0.018; rat, 0.004; cardiac muscle of cat, 0.084; dog, 0.066; rat, 0.042. From micrometry in hamster cheek pouch, in vivo compared with injected, effective capillary capacity/maximum capacity = 1/6. /5/ Calculated, excluding Items 28-34, 40-42, 45-47. /6/ By both hydrodynamic and injection methods, mammalian capillary surface area = 7.0 cu mm/cu mm, assuming that muscle density = 1.0. /7/ Muscle or animal stimulated before injection. /8/ Classified as working (W) on basis of habitual use. /9/ Low values for RBC diameter may be caused by shrinkage upon fixation.

Part II: CARDIAC MUSCLE

A = atrophied; H = hypertrophied; T = trained; U = untrained.

Animal	Heart Area		Capillaries per sq mm Cross-section ¹	Capillaries per Fiber	Capillary Diameter ² μ	Capillary Capacity ^{1, 3, 4} cu mm/cu mm	Capillary Surface Area ^{1, 4} sq mm/cu mm
1 Man, 5.9 yr			3744	0.3	8.4	0.207	98.8
2			3343	0.8	8.4	0.185	88.2
3		H	2483	0.8	8.4	0.138	65.5
4		A	4613	0.6	8.4	0.256	121.7
5 Guinea pig			1970		7.5	0.087	46.4
6		U	1948		7.5	0.086	45.9
7		T	2819		7.5	0.125	66.4
8			3407		7.5	0.151	80.3
9		H	2950		7.5	0.130	69.5
10 Rabbit	Left ventricle		3420	1.1	7.5	0.151	80.6
11		H	2670	1.2	7.5	0.118	62.9
12	Right ventricle		3310	1.0	7.5	0.146	78.0
13		H	2740	1.2	7.5	0.121	64.6
14 Snake (Tropido-	Papillary		3230		5.0	0.063	50.7
15 notus natrix)	Inner		500		14.5 ⁵	0.083	22.8
16	Periphery		1000	14.5 ⁵	14.5 ⁵	0.165	45.6

/1/ See Fn 2, Part I. /2/ Based on RBC diameter, excluding Item 14. /3/ See Fn 4, Part I. /4/ Calculated, excluding Item 14. /5/ Based on RBC dimensions of Natrix sp, 18.3 x 14.4 μ.

275. CIRCULATION TIME: VERTEBRATES

Circulation time is the time required for an indicator substance introduced into the blood stream to traverse the normal vascular path from a specified point, usually the point of introduction (as the antecubital vein in the arm), and to arrive at another point or area in sufficient concentration to register its arrival in some characteristic and recognizable manner. Values in parentheses are ranges, estimate "d" of the 95% range (cf Introduction).

Species	Circuit	Registration Time sec	Indicator	Species	Circuit	Registration Time sec	Indicator
1 Man	Arm to heart, left ventricle	8(6-9)	Diiodrast	56 Cat	Left common carotid art. to right auricle	6(3-9.5)	Radium-C
2 Adult	Arm to heart, right atrium	3.6(1.6-10)	Acetylcholine	57	Femoral vein to carotid artery	3.2(3-3.5)	Conductivity
3	Arm to lung	6.6(3.5-8)	Ether	58		4(3-5)	Radioactive phosphorus ⁷
4		6(3-9)	Paraldehyde	59	Femoral artery to carotid artery	10(9-11)	Radioactive phosphorus ⁷
5	Arm to carotid sinus	11(3-24)	Lobeline	60	Femoral artery to femoral vein	6(4-8)	Radioactive phosphorus ⁷
6		9.5(8-11)	α -Lobeline	61 Chicken	Sciatic vein to systemic arterioles	3	Acetylcholine
7		15.6(9-21)	Sodium cyanide ¹	62 Cow	Mammary vein to opposite mammary vein	52	Fluorescein
8	Arm to lips	17.5(15-20)	Fluorescein ²	63 Dog	Root of aorta to sino-atrial node	1.3(1.1-1.7)	Acetylcholine
9	Arm to mouth	12(9-15)	Calcium chloride	64	Apex left ventricle to s-a node	1.8(1.7-2.1)	Acetylcholine
10	Arm to face	21.5(13-30)	Histamine	65	2-3 cm above root of aorta to s-a node	3.4(2.6-4.3)	Acetylcholine
11	Arm to tongue	12(9-15)	Calcium chloride	66	Main pulmonary artery to s-a node	5.2(3.9-7.6)	Acetylcholine
12		13(10-16)	Calcium gluconate	67	Right ventricle to s-a node	6(4.4-6.8)	Acetylcholine
13		14.4(8-20)	Decholin	68	Leg vein to s-a node	6.7(4.0-9.5)	Acetylcholine
14		15(5-24)	Macasol ³	69	Superior vena cava to s-a node	6.7(6.4-9.9)	Acetylcholine
15		12.4(7-17.8)	Magnesium sulfate	70	Femoral vein to right atrium	17(16-18)	Bismuth oil
16		11.6(9-16)	Saccharin	71	Systemic (greater circulation)	5.3(3.5-7.1)	Conductivity
17	Arm to tongue and nose	8.5(5-13)	Thiamine	72	Pulmonary (lesser circulation)	5.8(4.0-7.6)	Conductivity
18	Arm to throat	18(12-25)	Calcium gluconate	73	Right to left ext. jugular vein	9.25	Conductivity
19		14(7-22)	Macasol ³	74	Complete circulation	10.8(8.9-12.8)	Conductivity
20		14(11-17)	Magnesium sulfate	75	Femoral vein to conjunctiva	12.6	Fluorescein
21	Arm to conjunctiva	10.6(7-16)	Fluorescein	76	Right to left jugular vein	7.9(4.9-10.2)	Hexamethylene tetramine
22	Arm to ear	12.5(9-16)	Methylene blue ⁴	77	Right to left ext. jugular vein	7.8	Lithium acetate
23		14(10-21)	Dye(T-1824) ⁵	78	Right to left jugular vein	7.8(4.9-10.2)	Lithium benzoate
24	Arm to respiratory center	15(12-19)	Aminophylline	79	Femoral vein to carotid artery	7(6-8)	Radioactive phosphorus
25		21(15-27)	Papaverine	80	Jugular vein to right heart	1.7(1-2.5)	Shadacol ⁹
26	Arm to arm	23(18-30)	Fluorescein	81	Right to left heart	5.5	Shadacol ⁹
27		17.5(12-23)	Radium-C	82	Left to right heart	6.0	Shadacol ⁹
28		19(14.5-26.2)	Riboflavine	83	Femoral vein to carotid sinus	8.0	Sodium cyanide
29		15(10-20)	Thorium-X	84	Ext. jugular vein to carotid sinus	(9-13)	Sodium cyanide
30	Arm to opposite hand	25.5(23-28)	Fluorescein	85	Left ventricle or aorta to femoral artery	4.0	Sodium sulfocyanide
31		27(26-28)	Macasol ³	86	Complete circulation	10.5(10-11)	Sodium sulfocyanide
32	Arm to foot, open wound	23	Fluorescein	87 Goat	Pulmonary circulation, fetal	4.7	Iodine
33	Arm to foot, intact skin	35(34-36)	Fluorescein	88	Pulmonary circulation, birth	2.7	Iodine
34		32.5(28-37)	Macasol ³	89 Horse	Jugular vein to opposite jugular vein	22.5(20-25)	Potassium ferrocyanide
35	Arm to perineum	26	Macasol ³	90 Sheep	Pulmonary circulation, fetal	2.7	Iodine
36	Arm to rectum	18	Fluorescein	91 (lamb)	Pulmonary circulation, birth	1.4	Iodine
37	Right to left heart (lesser)	6.5	Radium-C	92	Complete circulation	(5-8)	Iodine
38	Through heart	1	Radium-C	93 Rabbit	Pulmonary circulation	2.85	Conductivity
39	Lung to face	19.5(14-25)	Amyl nitrite	94	Crural artery to crural vein	3.8	Conductivity
40	Lung to medulla	7(5-10)	Carbon dioxide	95	Hepatic portal circulation	5.4(3.85-6.95)	Conductivity
41	Lung to ear	5.2(4-7)	Nitrogen, 100% ⁶	96	Renal circulation	8	Conductivity
42	Lung to opposite lung	(10-15)	Acetylene	97	Jugular vein to crural vein	8.4	Conductivity
43	Foot to tongue	41(22-75)	Histamine	98	Complete circulation	10.5	Conductivity
44	Foot to groin	18(6-49)	Radioactive sodium	99	Ear vein to eye	5.5(5-6)	Fluorescein
45	Foot to carotid sinus	33(27-39)	Sodium cyanide	100	Right to left ear vein	4.8(3.4-7.2)	Hexamethylene tetramine
46	Portal circ., rectum to lung	(11-25)	Ether	101		4.7	Lithium acetate
47	Total circulation	8(7-9)	Radioactive phosphorus ⁷	102		4.5(3.5-5.8)	Lithium chloride
48 Children	Arm to carotid sinus	10.6 ⁸ (9-14.5)	Sodium cyanide	103		6.0	Methylene blue ⁴
49	Arm to tongue or nose	6(4-8)	Thiamine	104	Ear vein to medulla	4(3.3-5.2)	Sodium cyanide
50	Arm to opposite arm	11(5-17)	Radioactive sodium	105	Ear vein to carotid sinus	3.9	Sodium cyanide
51		8.9	Riboflavine	106	Right jugular vein to right carotid art.	(2.4-3.4)	Sodium chloride
52 Newborn	Arm to conjunctiva	(5-14)	Fluorescein	107	Left jugular vein to right femoral art.	(3.85-4.0)	Sodium chloride
53	Umbilical vein to lip	(3.1-7)	Fluorescein	108	Left to right jugular vein	(4.1-6.1)	Sodium chloride
54	Ductus venosus to lip	(3.3-6)	Fluorescein	109	Left jugular vein to right renal artery	(3.8-5.4)	Sodium chloride
55	Umbilical vein to umbilical vein	(30-60)	Congo red	110	Left jugular vein to right renal vein	(10.8-12.7)	Sodium chloride

/1/ Warm subject, 18.5; cold subject, 32.3. /2/ During exercise, 6. /3/ Magnesium sulfate compound. /4/ Photoelectric method. /5/ Photocell. /6/ With oximeter. /7/ Labelled cells. /8/ For ages 14 days to 5.9 yr; 10.4 for ages 6-12.9 yr. /9/ Iodophthalen sodium.

276. BLOOD VESSELS: MAN

ant.=anterior; ext.=external; inf.=inferior; int.=internal; lt.=left; mid.=middle; post.=posterior; rt.=right; sup.=superior; trans.=transverse.

Part I: ARTERIES

Listed arteries represent important blood pathways. A complete atlas is not intended and branches of main arteries, in many cases, are not shown.

Artery	Origin	Distribution	Artery	Origin	Distribution
1 Alveolar, inferior	Internal maxillary	Lower teeth, gums, mandible, lower lip, chin.	79 Innominate	Arch of aorta	Right side of head, neck, upper limb.
2 Superior, anterior	Infraorbital	Incisors, canines of upper jaw.	80 Intercostal	Int. mammary, thoracic	Thoracic walls, muscles, vertebrae.
3 Superior, posterior	Internal maxillary	Molars, bicusps of upper jaw; maxillary sinus.	81 Interlobar (renal)	Renal	Kidney lobes,
4 Aorta, abdominal	Thoracic aorta	Abdominal viscera, wall; pelvis; lower limbs.	82 Interosseous, anterior	Ulnar	Deep structures of forearm.
5 Ascending, arch	Left ventricle	Heart muscle, head, neck, upper limbs.	83 Lacrimal	Ophthalmic	Lacrimal gland, eye muscles, cheek, eyelids.
6 Thoracic	Aortic arch	Thoracic wall, mediastinal structures.	84 Laryngeal, inferior	Inferior thyroid	Larynx, upper trachea, esophagus.
7 Appendicular	Ileocolic	Mesentery of vermiform appendix.	85 Superior	Superior thyroid	Larynx, pharynx.
8 Arcuate (renal)	Interlobar	Kidney parenchyma.	86 Lenticular	Middle cerebral	Lenticular nucleus.
9 Auditory, internal	Anterior inf. cerebellar	Internal ear.	87 Lingual	External carotid	Tongue, tonsil, sublingual gland, epiglottis.
10 Auricular, anterior	Superficial temporal	Lat. surface auricle, external meatus.	88 Lumbar (4 pairs)	Abdominal aorta	Abdominal walls, vertebrae, lumbar muscles, renal capsule.
11 Auricular, posterior	External carotid, 5th branch	Middle ear, mastoid cells, auricle, parotid gland, digastric and other muscles.	89 Mammary, interior	Subclavian	Anterior thoracic wall, mediastinal structures.
12 Axillary	Subclavian	Upper extremity, axilla, chest, shoulder.	90 Maxillary, external	External carotid	Face, tonsil, palate, submaxillary gland.
13 Basilar	Right and left vertebral	Brain stem, internal ear, cerebellum, posterior cerebrum.	91 Internal	External carotid	Both jaws, teeth, chewing muscles, ear, meninges, nose, nasal sinus, palate.
14 Brachial	Axillary	Shoulder, arm, forearm, hand.	92 Median	Volar interosseous	Median nerve, muscles of front forearm.
15 Superficial	Brachial or axillary	Radial, or radial and ulnar arteries.	93 Medullary (arteriolae rectae)	Arcuate of kidney	Renal pyramids.
16 Bronchial	Aorta or intercostal	Bronchi, lungs.	94 Meningeal, anterior	Ophthalmic, interior carotid	Bones, dura mater of anterior cranial fossa.
17 Carotid, common	Innominate, right; aortic arch, left	Origin of external and internal carotids.	95 Middle or great	Internal maxillary	Bones, dura mater of middle cranial fossa.
18 External	Common carotid	Neck, face, skull.	96 Posterior	Ascending pharyngeal	Bones, dura mater of posterior cranial fossa.
19 Internal	Common carotid	Mid-ear, brain, pituitary, orbit, choroid plexus of lateral ventricle.	97 Mesenteric, inferior	Abdominal aorta	Lower half of colon, rectum.
20 Celiac	Abdominal aorta	Esophagus, stomach, duodenum, spleen, pancreas, liver, gallbladder.	98 Superior	Abdominal aorta	Small intestine, proximal half of colon.
21 Central of retina	Ophthalmic	Retina.	99 Metacarpal, dorsal	Radial, ulnar, interosseous.	Hand and fingers, dorsal.
22 Cerebellar, ant. inf.	Basilar	Lower anterior cerebellar cortex.	100 Metatarsal, dorsal	Dorsalis pedis	Foot and toes, dorsal.
23 Posterior inferior	Vertebral	Lower cerebellum, medulla, choroid plexus 4th ventricle.	101 Musculophrenic	Internal mammary	Diaphragm; abdominal, thoracic walls.
24 Superior	Basilar	Upper cerebellum, mid-brain, pineal body, choroid plexus 3rd ventricle.	102 Obturator	Hypogastric	Pelvic muscles, hip joint, ant. thigh.
25 Cerebral, anterior	Internal carotid	Frontal lobe, medial surface cerebrum, corpus callosum.	103 Occipital	External carotid	Scalp, neck muscles, post.
26 Middle	Internal carotid	Lateral surface cerebrum and basal ganglia.	104 Ophthalmic	Internal carotid	Eye, orbit, adjacent facial structures.
27 Posterior	Basilar	Occipital, temporal lobes, basal ganglia, choroid plexus of lateral ventricle.	105 Ovarian	Abdominal aorta	Ovary, ureter, uterus, uterine tube.
28 Cervical, ascending	Inferior thyroid	Neck muscles, vertebrae, spinal canal.	106 Palatine, ascending	External maxillary	Soft palate, tonsil, auditory tube.
29 Deep	Costocervical	Deep muscles of back of neck; first intercostal	107 Descending	Internal maxillary	Soft, hard palates; tonsil.
30 Transverse	Thyrocervical trunk	Posterior muscles of neck, interscapular region.	108 Pancreatic	Splenic	Pancreas.
31 Choroid	Internal carotid	Choroid plexus of lateral ventricle, hippocampus fimbria.	109 Pancreaticoduodenal		
32 Ciliary, ant., post.	Ophthalmic and lacrimal	Iris, conjunctiva, choroid.	110 Inferior	Superior mesenteric	Pancreas, duodenum.
33 Circumflex, femoral			111 Superior	Gastroduodenal	Pancreas, duodenum.
34 Lateral	Profunda femoris	Hip joint, thigh muscles.	112 Penis, deep, dorsal.	Internal pudendal	Penis.
35 Medial	Profunda femoris	Hip joint, thigh muscles.	113 Perforating	Profunda femoris	Muscles of thigh.
36 Iliac, deep	External iliac	Abdominal muscles.	114 Pericardiacophrenic	Internal mammary	Pericardium, diaphragm, pleura.
37 Superficial	Femoral	Inguinal glands, skin of thigh and abdomen.	115 Perineal	Internal pudendal	Perineum, skin of external genitalia.
38 Colic, left	Inferior mesenteric	Descending colon.	116 Phrenic, inferior	Posterior tibial	Outside and back ankle, deep calf muscles.
39 Middle	Superior mesenteric	Transverse colon.	117 Plantar arch	Aorta, abdominal	Diaphragm, suprarenal glands.
40 Right	Superior mesenteric	Ascending colon.	118 Pontine	Lateral plantar	Sole of foot, toes.
41 Collateral, ulnar	Brachial	Lower arm and elbow.	119 Popliteal	Basilar	Pons, brachia pontis, trigeminal roots.
42 Communicating, ant.	Anterior cerebral	Anterior perforated substance.	120 Princeps pollicis	Femoral	Knee, post. leg.
43 Posterior	Internal carotid	Uncinate gyrus, thalamus.	121 Profunda brachii	Radial	Thumb ventrally.
44 Coronary, left	Left aortic sinus	Heart.	122 Profunda femoris	Brachial	Humerus, posterior arm structures.
45 Right	Right aortic sinus	Heart.	123 Pudendal, external	Femoral	Thigh muscles, hip joint.
46 Cystic	Hepatic	Gallbladder, under surface of liver.	124 Internal	Femoral	External genitalia, medial thigh muscles.
47 Digital (of fingers)	Metacarpals	Fingers.	125 Pulmonary	Hypogastric	Perineum, anal canal, external genitalia.
48 Digital (of toes)	Metatarsals	Toes.	126 Radial	Right ventricle	Lungs.
	Pericranial, meningeal	Diploe of skull.	127 Renal	Brachial	Forearm, wrist, hand.
			128 Sacral, lateral	Abdominal aorta	Kidney.
			129 Middle	Hypogastric	Structures about coccyx and sacrum.
			130 Scapular, trans.	Aorta	Sacrum and coccyx.
			131 Scrotal, anterior	Thyreocervical	Clavicle, scapula, shoulder muscles, joint.
			132 Posterior	External pudendal	Anterior part of scrotum.
				Perineal	Posterior part of scrotum.

49	Dorsalis pedis	Anterior tibial	Dorsum of foot, toes.	133	Septal (nasal)	Sphenopalatine	Mucous membrane of nasal septum, palate.
50	Epigastric, inferior	External iliac	Abdominal muscles, cremaster, peritoneum.	134	Sigmoid	Inferior mesenteric	Sigmoid flexure of colon.
51	Superficial	Femoral	Skin of abdomen, superficial fascia.	135	Spermatic, internal	Abdominal aorta	Testis.
52	Superior	Internal mammary	Abdominal muscles, diaphragm.	136	Sphenopalatine	Internal maxillary	Interior of nose and nasal sinus.
53	Esophageal	Gastric, inferior thyroid, left phrenic, thoracic	Esophagus.	137	Spinal, ant., post.	Intercostal, lumbar	Spinal cord.
54	Ethmoidal anterior	Ophthalmic	Dura mater, nose, frontal sinus, ant. and mid. ethmoidal cells.	138	Splenic	Celiac	Spleen, pancreas, stomach, greater omentum.
55	Posterior	Ophthalmic	Posterior ethmoidal cells, nose, dura mater.	139	Stapedial	Stylomastoid	Stapedius muscle.
56	Femoral	External iliac	Lower abdominal wall, ext. genitalia, lower limb.	140	Stylomastoid	Posterior auricular	Tympanic cavity walls, mastoid cells, semicircular canals.
57	Deep	Femoral	Thigh muscles, hip joint.	141	Subclavian	Innominate (right side), aortic arch (left side)	Neck, thoracic wall, spinal cord, brain, meninges, upper limbs.
58	Frontal	Ophthalmic	Anterior scalp.	142	Subcostal	Thoracic aorta	Region below 12th rib in abdominal wall.
59	Gastric, left	Celiac	Esophagus, lesser curvature of stomach.	143	Submental	External maxillary	Tissues under chin.
60	Right	Hepatic	Lesser curvature of stomach.	144	Subscapular	Axillary	Back of axilla, shoulder and scapular muscles.
61	Short	Splenic	Left portion greater curvature of stomach.	145	Supra-orbital	Ophthalmic	Forehead, upper muscles of orbit.
62	Gastroduodenal	Hepatic	Stomach, duodenum, pancreas.	146	Suprarenal, inferior	Renal	Suprarenal gland.
63	Gastroepiploic, left	Splenic	Stomach, greater omentum.	147	Middle	Aorta	Suprarenal gland.
64	Right	Gastroduodenal	Stomach, greater omentum.	148	Superior	Inferior phrenic	Suprarenal gland.
65	Gluteal	Hypogastric	Hip joint, gluteal region.	149	Temporal, superficial	Exterior carotid	Parotid, auricle, scalp.
66	Hemorrhoidal, sup.	Inferior mesenteric	Upper part of rectum.	150	Thymic	Internal mammary	Mediastinum, thymus.
67	Middle	Hypogastric	Middle portion of rectum.	151	Thyroid, inferior	Thyroecervical trunk	Larynx, esophagus, trachea, neck muscles, thyroid.
68	Inferior	Internal pudendal	Anal canal.	152	Superior	External carotid	Hyoid muscles, larynx, thyroid, pharynx.
69	Hepatic	Celiac	Stomach, pancreas, duodenum, liver.	153	Thyroidea ima	Aortic arch, innominate	Thyroid gland.
70	Left	Hepatic	Left lobe of liver.	154	Tibial, anterior	Popliteal	Leg, ankle, foot, dorsal.
71	Right	Hepatic	Right lobe of liver.	155	Posterior	Popliteal	Leg, sole of foot, heel.
72	Hypophyseal	Internal carotid	Hypophysis.	156	Tonsillar	Ascending palatine	Tonsil, neighboring tissues
73	Intestinal	Superior mesenteric	Ileum, jejunum.	157	Tympanic	Int. maxillary, ext. carotid	Tympanic cavity.
74	Ileo-colic	Superior mesenteric	Cecum, appendix, ascending colon.	158	Ulnar	Brachial	Forearm, wrist, hand.
75	Iliac, common	Abdominal aorta	Pelvis, abdominal wall, lower limb.	159	Uterine	Hypogastric	Uterus, vagina, fallopian tube, round ligament.
76	Int. and ext.	Common iliac	Abdominal wall, external genitals, lower limb.	160	Vaginal	Hypogastric, uterine	Vagina, base of bladder, rectum.
77	Iliolumbar	Posterior hypogastric	Pelvic muscles, bones; 5th lumbar segment.	161	Vertebral	Subclavian	Neck muscles, vertebrae, spinal cord, brain, cerebellum, interior of cerebrum.
78	Infra-orbital	Internal maxillary	Maxilla, maxillary sinus, upper teeth, lower lid, cheek, side of nose.				

Part II: VEINS

Veins, venous sinuses and plexuses having no accompanying artery of the same name, or differing considerably from the accompanying artery, are listed. Veins having tributaries with the same distribution and name as the accompanying arteries are not shown.

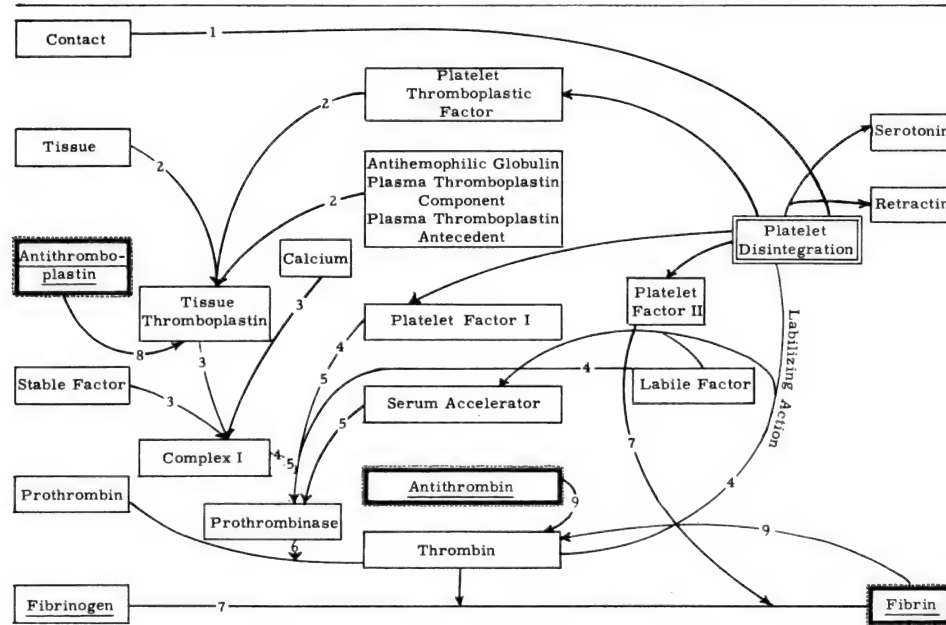
Vein	Location	Drains Into:	Vein	Location	Drains Into:
1 Accessory hemiazygos	Lt. side of vertebral column. ¹	Either azygos or hemiazygos.	24 Parumbilical	Round ligament of liver.	Portal.
2 Anterior facial	Anterior face.	With post., forms common facial.	25 Portal	Lesser omentum.	Sinusoids of liver.
3 Anterior jugular	Near midline of neck.	Ext. jugular or subclavian.	26 Prostatic plexus	Fascial sheath of prostate.	Pudendal and vesical plexuses.
4 Azygos	Rt. side of vertebral column. ¹	Superior vena cava.	27 Pterygoid plexus	Between pterygoid muscles.	Internal maxillary.
5 Basilic	Medial side of arm.	Joins brachial to form axillary.	28 Pudendal plexus	Behind symphysis pubis, in front of bladder.	Vesical and hypogastric veins.
6 Cavernous sinus	Middle cranial fossa.	Int. jugular via sup. petrosal sinus.	29 Pyloric	Lesser curvature of stomach.	Portal.
7 Cephalic	Lateral side of arm.	Axillary.	30 Sigmoid sinus	Groove on internal surface of temporal bone on petrous and mastoid parts.	Internal jugular.
8 Common facial	Below angle of mandible.	Internal jugular.	31 Small saphenous	Back of leg.	Popliteal.
9 Coronary sinus of heart	Post. part coronary sulcus.	Right atrium.	32 Straight sinus	Junction of falx cerebri with tentorium cerebelli.	Transverse sinus.
10 Coronary of stomach	Lesser curvature of stomach.	Portal.	33 Sup. sagittal sinus	Attached margin falx cerebri.	Confluence of sinuses or transverse sinus.
11 Emissary	Various apertures of skull.	Intracranial venous sinuses, connecting with veins external to skull.	34 Sup. vena cava	Behind first and second intercostal spaces and right margin of sternum.	Right atrium.
12 External jugular	Side of neck, superficial.	Subclavian.	35 Trans. sinus	Attached margin tentorium cerebelli.	Internal jugular via sigmoid sinus.
13 Great cardiac	Ant. longitudinal sulcus of heart.	Coronary sinus.	36 Vertebral plexus	Within vertebral canal (internal) and around vertebrae (external).	Intracranial venous sinus, segmental tributaries of various parietal and visceral veins.
14 Great cerebral	Below and behind splenium of corpus callosum.	Straight sinus.	37 Vesical plexus	Lower bladder, base prostate gland.	Hypogastric.
15 Hemiazygos	Lt. side of vertebral column. ¹	Azygos.	38 Vorticose	Eyeball.	Ciliary, ophthalmic veins.
16 Hemorrhoidal plexus	Rectum.	Sup., mid., inf. hemorrhoidal veins.			
17 Hepatic	Posterior surface liver.	Inferior vena cava.			
18 Inf. petrosal sinus	Inferior petrosal sulcus of skull.	Internal jugular.			
19 Inf. sagittal sinus	Lower edge of falx cerebri.	Straight sinus.			
20 Inf. vena cava	Front of lumbar vertebral column, right of aorta.	Right atrium.			
21 Innominate	Root of neck.	Superior vena cava.			
22 Internal jugular	Side of neck.	Innominate.			
23 Oblique of left atrium	Back of left atrium.	Coronary sinus.			

/1/ In thorax.

277. BLOOD COAGULATION: THEORIES

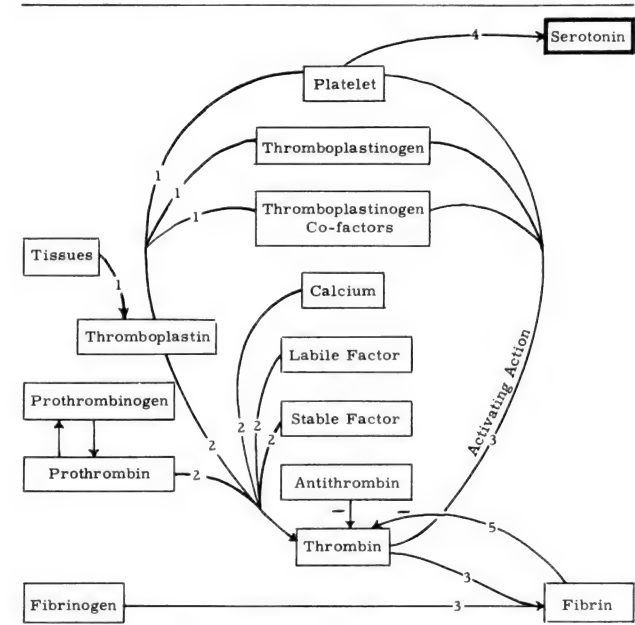
At the present time the concept of blood coagulation is more uncertain than it was before discovery of the newer clotting factors. It must be recognized that these charts are merely guides and will require modification as new data become available.

Part I: THEORY OF M. STEFANINI

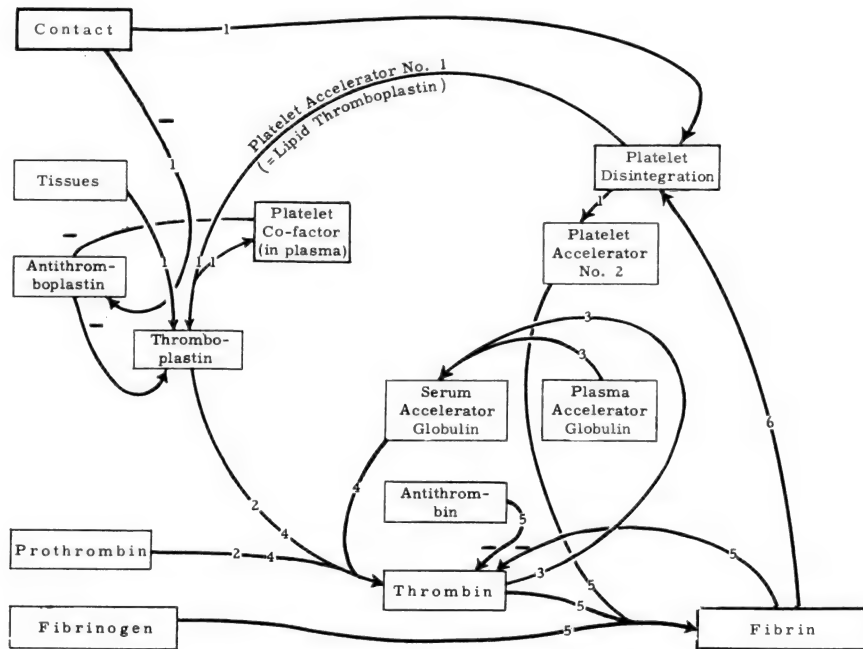


/1/ Contact with foreign surface (wounded vessel wall) causes disintegration of platelets. This is followed by the liberation of a number of agents present in or carried by platelets: serotonin (factor of vascular contractility), retractorin (clot retraction agent), thromboplastic factor, platelet factors I and II. There is increasing evidence that platelet factor I is only a labile factor absorbed on platelets. Evidence for platelet factor II is somewhat meager and this factor might be disregarded in future theories. /2/ Platelet thromboplastin factor interacts with a number of plasma factors (antihemophilic globulin, plasma thromboplastin component, plasma thromboplastic antecedent, possibly others) to form the equivalent of tissue thromboplastin. This, of course, may be supplied directly from tissue. /3/ Tissue thromboplastin, calcium and stable factor (proconvertin, factor VII, etc.) interact to form an intermediary complex (convertin). /4/ The intermediary complex (complex I) reacts with the labile factor (proaccelerin, factor V) to form a new agent (prothrombinase). Some prothrombin is then converted to thrombin and this initiates the "autocatalytic phase" of blood coagulation. Thrombin then determines further disintegration of platelets and also conversion of the labile factor to a more active accelerator of the conversion of prothrombin, the serum accelerator (accelerin). /5/ As result of the autocatalytic reaction, the formation of prothrombinase proceeds at an even more accelerated speed. A factor liberated from platelets (factor I) takes part in this reaction. /6/ Prothrombinase, formed in large quantities, converts almost completely prothrombin to thrombin. /7/ Thrombin converts fibrinogen to fibrin. A platelet factor (factor II) and a hypothetical plasma factor (not shown in the diagram) accelerate the formation of fibrin. /8/ Inhibitors exist for each phase and each blood coagulation factor. Antithromboplastin is a well documented one and antagonizes the activity of tissue thromboplastin. /9/ The conversion of fibrinogen to fibrin is also antagonized by two factors: a plasma antithrombin and the fibrin clot itself, through its property of adsorbing thrombin.

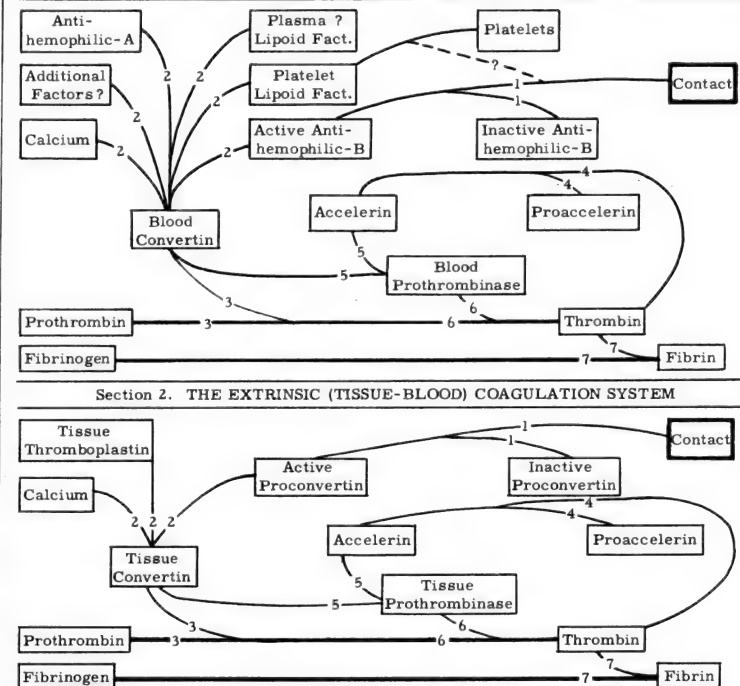
Part II: THEORY OF A. J. QUICK



/1/ Thromboplastin is (a) released by injured tissue and is (b) formed in the blood by the interaction of a platelet factor, thromboplastinogen (antihemophilic factor), and one or more co-factors (PTC, PTA, etc.) through the activating action of thrombin. /2/ Thromboplastin, prothrombin, calcium and labile factor interact stoichiometrically and, in addition, stable factor is needed to form thrombin. In adult human blood a large fraction of the prothrombin is in an inactive state: prothrombinogen (probably as a prothrombin inhibitor complex). During storage or clotting all prothrombinogen becomes activated. /3/ The thrombin formed not only converts fibrinogen to fibrin but participates in the activation of plasma factors (probably thromboplastinogen or one of its co-factors), thereby bringing about lysis of platelets and initiating a chain reaction. /4/ The platelets release a vasoconstrictor, serotonin, through the action of thrombin, which probably functions in local hemostasis. /5/ The prompt removal of thrombin by fibrin holds in check the autocatalytic reaction mediated through the action of thrombin on platelets, thromboplastinogen and its co-factors.



1/1 Contact of the blood with certain surfaces (damaged blood vessel endothelium, glass) initiates the first changes which lead to the inception of clotting; blood platelets agglutinate, adhere to the surface and/or disintegrate, releasing (a) cephalin like accelerator and (b) fibrinolytic factor (platelet accelerator No. 2). There is dissociation of the platelet co-factor/lipid inhibitor complex, with freeing of the platelet co-factor. The latter conjugates with the platelet lipid accelerator and forms plasma thromboplastin. Some of the thromboplastin of the blood is offset or neutralized by the antithromboplastin; some of the antithromboplastin is itself adsorbed or neutralized at the contacting surface. 1/2 Thromboplastin (from tissues and/or platelets) brings about a minimal conversion of prothrombin to thrombin. 1/3 This initially formed thrombin activates the accelerator system, that is, the conversion of inactive plasma accelerator globulin to active serum accelerator globulin. 1/4 Thromboplastin together with serum accelerator globulin causes acceleration of the conversion of prothrombin to thrombin. 1/5 Some of the thrombin may be inactivated by antithrombin. The thrombin that escapes such inactivation acts, with the aid of platelet accelerator No. 2, to cause the conversion of fibrinogen to fibrin. Some of the excess thrombin is removed from the plasma by adsorption on fibrin. 1/6 Fibrin probably causes further disintegration of platelets.



(1) The intrinsic blood coagulation system: /1/ Contact activates the inactive antihemophilic B factor. (Plasma thromboplastin component, Christmas factor.) /2/ Reactions take place between plasma thromboplastin factors (antihemophilic A-factor (A.H.G.) and active antihemophilic B factor), lipid factors with cephalin-like activity (from platelets and possibly also in plasma) and calcium to form an intermediate complex termed blood convertin. This reaction possibly requires one or more additional factors such as: plasma thromboplastin antecedent, the IV thromboplastin factor, factor X, Prower factor. The problems of platelet disintegration and the significance of contact influence on platelets are still unsolved. /3/ Blood convertin brings about a minimal conversion of prothrombin to thrombin. /4/ This initially formed thrombin starts the accelerator system, i.e., the conversion of proaccelerin to accelerin. /5/ Blood convertin and accelerin interact in the presence of calcium to form blood prothrombinase. /6/ Blood prothrombinase produces rapid conversion of prothrombin to thrombin. /7/ Thrombin is now formed in sufficient quantity to convert fibrinogen to fibrin. NB: Proconvertin does not take part in the intrinsic blood coagulation system.

(2) The extrinsic (tissue-blood) coagulation system: /1/ Contact activates inactive proconvertin to active proconvertin. /2/ Tissue thromboplastin (liberated by tissue injury), active proconvertin and calcium interact to form tissue convertin. /3/ Tissue convertin brings about a minimal conversion of prothrombin to thrombin. /4/ This initially formed thrombin starts the accelerator system, i.e., the conversion of proaccelerin to accelerin. /5/ Tissue convertin and accelerin interact in the presence of calcium to form tissue prothrombinase. /6/ Tissue prothrombinase produces rapid conversion of prothrombin to thrombin. /7/ Thrombin is now formed in sufficient quantity to convert fibrinogen to fibrin. NB: Platelets and antithromphobic factors do not take part in the extrinsic blood coagulation system.

278. CARDIOVASCULAR REFLEXES: MAMMALS

[CIC = cardio-inhibitor center; CAC = cardio-accelerator center; VCC = vasoconstrictor center; N = nerve; NN = nerves.

Reflex		Effective Stimulus	Reflex Pathway				Response	Species ¹	Conditions in which Reflex is Increased
			Receptor	Afferent	Center	Efferent			
1	Veno-cardiac (Bainbridge)	Blood pressure↗ in great veins, R auricle.	Walls of great veins entering R auricle; wall of R auricle(?).	Vagus N (afferent fibers).	CIC↘ CAC↗	Vagus N; sympathetic(?).	Heart rate↗.	Man, dog(?) ²	Exercise; inspiration; R ventricular failure.
2	Veno-arterial (McDowall)	Blood pressure↘ in great veins.			VCC↗	Sympathetic NN.	General arterial vasoconstriction retards↘ in arterial blood pressure.	Man	Hemorrhage; erect posture.
3		Blood pressure↗ in great veins, R auricle.					General arterial vasoconstriction; arterial blood pressure↗.	Dog, cat	Exercise.
4	Pulmonary vaso-cardiac ³	Pulmonary blood pressure↗; distension lung vessels.	Pulmonary arteries(?); VV(?); capillaries(?).	Vagus N (afferent fibers).	CIC↘ CAC↗	Vagus N.	Heart rate↗.	Man	Exercise; L ventricular, L auricular failure.
5	Pulmonary alveolo-cardiac ³	"Collapse of lung alveoli."	Pulmonary alveoli.		CIC↘ CAC↗	Vagus N; sympathetic(?).			Lung consolidation, collapse; extreme expiration.
6	Aorto-cardiac	Aortic pressure↗ ⁴ .	Wall of aortic arch.	Vagus N (afferent fibers).	CAC↘ CIC↗	Vagus N; sympathetic NN(?).	Heart rate↘.	Man, rabbit	Exercise; recumbent posture or lowered head; hypertension.
7	Aorto-arterial				VCC↘	Vasodilatation; arterial and venous blood pressure↘; syncope.			
8	Carotid sinus: Cardiac	Carotid blood pressure↗ ⁴ ; direct pressure on sinus.	Adventitia of carotid sinus.	Glossopharyngeal N; vagus N ⁵ .	CIC↘ CAC↗	Vagus N; sympathetic(?).	Heart rate↘.	Man	Exercise; recumbent posture or lowered head; pressure on neck.
9	Arterial	VCC↘			Sympathetic.	Vasodilatation; arterial and venous blood pressure↘; syncope ⁶ .			
10	Aortic & carotid body: Cardiac	Arterial blood O ₂ ↘; blood free CO ₂ ↗; blood pH↘.	Carotid-aortic body chemoreceptors.		CAC↘ CIC↗ VCC↘		Heart rate↗.	Man	Acetylcholine; acidosis; anemia; asphyxia; deep anesthesia.
11	Arterial					Blood pressure↗; vasoconstriction.			
12	Antigravity vascular reflexes ⁷	Pressure & voluntary changes associated with erect posture.	Brain(?); pacinian corpuscles(?).	Multiple(?).	CIC↘ VCC↗	Sympathetic NN.	Heart rate↗; splanchnic vasoconstriction; venous tone↗.	Man	Assumption of erect posture.
13	Myo-arterial (Loven)	Muscular contraction.	Receptors among fibers of skeletal muscle.	Afferent fibers in "motor" nerve trunks.	VCC↘ (local)	Vasodilatation NN; sensory NN.	Local vasodilatation; remote vasoconstriction; blood pressure↗.	Man(?), dog	Muscular activity.
14	Myo-cardiac				CIC↘	Vagus N.	Heart rate↗.	Man	Arterial compression; arterial obstruction (thrombosis, endarteritis).
15	Myo-arterial (Alam and Smirk)	Anoxic muscular activity.				VCC↘ (local)	Sympathetic; vasodilatation NN.			Blood pressure↗.
16	Pain N fibers: cardiac, arterial	Strong stimulated pain fibers; stimulated splanchnics.			CIC↘ VCC↗		Heart rate↘; splanchnic vasodilatation; blood pressure↘.	Man	Blow to jaw, epigastrium; painful injury or disease, e.g. colic.
18	Cold N fibers	Stimulation of skin cold receptors.		Cutaneous, sensory NN	VCC↘	Cutaneous, sensory.	Cutaneous vasoconstriction.	Man	Exposure to cold.
19	Thermo-arterial	Stimulation of skin heat receptors.		sensory NN	VCC↘	Sympathetic.	Cutaneous vasodilatation ⁸ .	Man	Exposure to heat.
20	Medullary cardio-inhibitor center (CIC) (vagus)	Reflex inhibition, cf 1, 4, 5, 10, 12, 14.	CIC		CIC↘ CAC↗	Vagus N; sympathetic NN.	Heart rate↗.	Man	Exercise; L or R heart failure; shock; erect posture.
21		Arterial blood free CO ₂ ↗, O ₂ ↘, pH↘.							Exercise; anemia; acetylcholine; asphyxia; acidosis.
22		Blood temperature↗.							Pyrexia.
23		Higher center inhibition (hypothalamus).							Emotion ⁹ ; fear, anxiety, (usual response).
24		Higher center stimulation (hypothalamus).							Emotion ⁹ ; disgust; anxiety, fear (less frequent response).
25	Medullary vasoconstrictor center (VCC)	Blood flow↘.	VCC		CIC↘ CAC↗	Sympathetic NN.	Vasoconstriction; blood pressure↗.	Man	Cerebral compression; tumor.
26		Reflex stimulation, cf 6, 8, 16.							Hypertension; blow to epigastrium.
27		Reflex stimulation, cf 2, 3, 11, 12, 13, 15, 18.							Exercise; R heart failure; erect posture; shock; hemorrhage.
28		Arterial blood free CO ₂ ↗, pH↘.							Exercise; CO ₂ inhalation; apnea.
29		Blood flow↘.							Shock; hemorrhage; heart failure with↘ output; tumor.
30		Higher center stimulation (hypothalamus, cortex).			VCC↘	Vagus N; sympathetic NN.	Splanchnic vasoconstriction; cutaneous vasodilatation or constriction; systolic blood pressure↗.	Man	Emotion ⁹ ; excitement, anger, rage.
31		Higher center inhibition (hypothalamus).				Splanchnic vasodilatation; blood pressure↘; fainting.	Emotion ⁹ ; fear, anger, rage.		
32		Blood temperature↗.				Cutaneous vasodilatation (flushing).	Fever.		
33		Reflex inhibition, cf 7, 9, 17.					Rise of blood pressure.		

/1/ These reflexes have been demonstrated only in the forms listed, but may have wide mammalian distribution. /2/ Best seen in animals with marked tonic vagal inhibition of heart rate; not seen in frog, rabbit; slight in cat. /3/ May be the same as Hering-Breuer reflex by irradiation from respiratory center to CIC. /4/ \searrow blood pressure has opposite effects. /5/ For aortic sinus and body. /6/ When sinus is hyperactive. /7/ A depressor reflex (\searrow blood pressure) from mesenteric vessels has been described for man, cat. /8/ Stimulation of heat receptors may actually cause vasoconstriction, the reflex vasodilatation resulting from removal of cold stimulus. /9/ Emotion is also associated with secretion of adrenalin.

279. ELECTRICAL PROPERTIES MEASURED WITH ALTERNATING CURRENTS: BODY TISSUES

Temperature coefficient of specific resistance: (a) $-2\%/^{\circ}\text{C}$ whenever frequency dependence is small; (b) complicated function of frequency, but always above $-2\%/^{\circ}\text{C}$ when frequency dependence is pronounced.
 Temperature coefficient of dielectric constant: (a) Smaller than 0.5% when frequency dependence is small; (b) positive, but complicated function of frequency when frequency dependence is pronounced.

cps=cycles per second; kc=kilocycles per second; Mc=megacycles per second.

Frequency	Muscle	Heart Muscle	Liver	Lung*	Spleen	Kidney	Brain	Fatty Tissue	Bone	Bone Marrow	Whole Blood	Plasma	0.9% NaCl
Specific Resistance (ohm cm)													
1 10 cps			1220 ¹										
2 100 cps			1050 ¹								166 ²		
3 1 kc	800 ¹	750 ¹	800 ¹	1000 ¹				1500-5000 ¹			166 ²	60 ²	
4 1 kc			970 ¹	400-850 ³				1700-2500 ³			147 ⁴		
5 1 kc		830-900 ⁵	1000-1600 ⁵	1400-1900 ⁵			500-800 ⁵				120-135 ⁵		
6 1 kc	980 ⁶		700-1300 ⁷		260-430 ⁷		450-550 ⁷				130-180 ⁸		
7 10 kc	880 ⁶		850 ¹								147 ⁴		
8 10 kc			460 ¹										
9 100 kc	170-250 ⁹	190-240 ⁹	220-550 ⁹	165-200 ⁹	250-500 ⁹	150-270 ⁹	460-850 ⁹				147 ⁴		
10 100 kc	520 ⁶		550-800 ⁷										
11 100 kc			420 ¹⁰										
12 1 Mc	160-210 ⁹	180-230 ⁹	210-420 ⁹	150-280 ⁹	230-380 ⁹	140-250 ⁹	430-700 ⁹				140 ⁴		
13 1 Mc			400-550 ⁷										
14 1 Mc	250 ⁶		400 ¹⁰										
15 10 Mc	150-170 ⁹	140-180 ⁹	180-260 ⁹	110-150 ⁹	150-170 ⁹	120-170 ⁹	300-450 ⁹				90 ⁴		
16 10 Mc			250 ¹⁰										
17 100 Mc	100-130 ¹¹	130-170 ⁹	120-145 ¹¹	95-130 ¹¹	85-105 ¹¹	100-120 ¹¹	160-230 ¹¹	1170-1250 ¹¹			82 ¹²	70 ¹²	
18 100 Mc	120-160 ⁹		150-200 ⁹	100-140 ⁹	110-150 ⁹	100-150 ⁹	200-300 ⁹	1500 ⁹			61 ¹¹	61 ¹¹	
19 100 Mc	140-200 ¹³		180-210 ¹³		150 ¹³	130-160 ¹³	220-260 ¹³	2200-4300 ¹³		4100-5300 ¹³	120-150 ¹³	80 ¹³	
20 100 Mc	120-150 ¹³		150-180 ¹³		120 ¹³	90-140 ¹³	180-200 ¹³	1700-2500 ¹³		3000-5000 ¹³	80-100 ¹³	60 ¹³	
21 1000 Mc	75-79 ¹⁴	83-100 ¹⁵	98-106 ¹⁴	137 ¹⁵		81-82 ¹⁵		700-1400 ¹⁴	2000 ¹⁴	1000-2300 ¹⁴	64-72 ¹⁴	54 ¹⁴	49 ¹⁴
22 1000 Mc	81-84 ¹⁵		92-100 ¹⁵					1100-3500 ¹⁵			80 ¹⁵		56 ¹⁵
23 1000 Mc	77 ¹⁶		100 ¹⁶					2500 ¹⁶					
24 10,000 Mc	12 ¹⁴		15-17 ¹⁴					240-370 ¹⁴	150 ¹⁴	60-200 ¹⁴	11 ¹⁴	9 ¹⁴	9 ¹⁴
25 10,000 Mc	13 ¹⁷							210 ¹⁷	130 ¹⁷	100 ¹⁷	9.5 ¹⁷		
26 10,000 Mc											9.3 ¹⁸		
Dielectric Constant (Relative to Vacuum)													
27 10 cps	2500x10 ³¹⁹		900x10 ³¹	450x10 ³¹				150x10 ³¹					
28 100 cps	800x10 ³¹	800x10 ³¹											
29 100 cps	1000x10 ³¹⁹												
30 1 kc	130x10 ³¹	300x10 ³¹	150x10 ³¹	90x10 ³¹				50x10 ³¹					
31 1 kc	170x10 ³¹⁹										2900 ⁴		
32 1 kc	100x10 ³⁶												
33 10 kc	50x10 ³¹	100x10 ³¹	50x10 ³¹	30x10 ³¹				20x10 ³¹					
34 10 kc	90x10 ³¹⁹										2810 ⁴		
35 10 kc	50x10 ³⁶												
36 100 kc	30x10 ³¹⁹		7,000-12,000 ⁷								2740 ⁴		
37 100 kc	20x10 ³⁶												
38 1 Mc	2x10 ³⁶		1200-2000 ⁷								2040 ⁴		
39 10 Mc											200 ⁴		
40 100 Mc	69-73 ¹³		65-75 ¹¹		88-90 ¹³	83-84 ¹³	70-75 ¹³	8-13 ¹¹			72-74 ¹³	82 ¹³	
41 100 Mc	71-76 ¹³		72-74 ¹³		100-101 ¹³	87-92 ¹³	81-83 ¹³	11-13 ¹³		7-8 ¹³	73-76 ¹³	76 ¹³	
42 100 Mc	49-52 ¹⁴		46-47 ¹⁴					4.3-7.5 ¹⁴	8 ¹⁴	4.3-7.8 ¹⁴	58-62 ¹⁴	69 ¹⁴	72 ¹⁴
43 1000 Mc	53-55 ¹⁵	53-57 ¹⁵	44-52 ¹⁵	35 ¹⁵		53-56 ¹⁵		3.2-6 ¹⁵			63 ¹⁵		78 ¹⁵
44 1000 Mc	61 ¹⁶		50 ¹⁶					9.5 ¹⁶					
45 10,000 Mc	40-42 ¹⁴		34-38 ¹⁴					3.5-3.9 ¹⁴	8 ¹⁴	4.4-6.6 ¹⁴	50-52 ¹⁴	61 ¹⁴	66 ¹⁴
46 10,000 Mc	29 ¹⁷							3.6 ¹⁷	6.6 ¹⁷	5.8 ¹⁷	45 ¹⁷		
47 10,000 Mc											48 ¹⁸		

* Partially or totally deflated, except material described in Footnote 1.

/1/ Dog, material in situ at body temperature. /2/ Sheep, material at 18°C, except plasma at 37°C (Line 3). /3/ Dog, in situ at body temperature. /4/ Rabbit, at room temperature. /5/ Rabbit, excised material at 37°C. /6/ Rabbit, excised piece at room temperature. /7/ Man and various animals, excised pieces and minced material at 23°C. /8/ Sheep, 18°C. /9/ Man, minced material at 23°C. /10/ Rabbit, minced material at 23°C. /11/ Man, minced material at 37°C. /12/ Sheep, at 20°C. /13/ Beef and pork, excised material at 20°C (Lines 19, 41), and at 37°C (Lines 20, 42). /14/ Dog and horse, blood and excised tissues measured at 38°C, except bone and bone marrow at 25°C. /15/ Man, excised piece at 27°C. /16/ Beef, minced material at 22°C. /17/ Man, excised piece at 37°C. /18/ Man, excised material at 35°C. /19/ Frog, excised piece at 25°C.

280. ELECTRO-PHYSIOLOGICAL PROPERTIES, EXCITABLE TISSUES: ANIMALS

Resting and action potential data are restricted to intracellular recording, unless otherwise noted. Values obtained with intracellular electrodes filled with 3M KCl are considered as corrected for junction potential. Values in parentheses are ranges. Space constant of fiber (λ) in paraffin oil = $\sqrt{r_m(r_o + r_i)}$, in cm, where r_o = resistance of outside fluid per unit length, in ohm-cm⁻¹; r_i = internal resistance of fiber per unit length, in ohm-cm⁻¹; and r_m = transverse resistance times unit length of fiber, in ohm-cm. Time constant of the membrane (τ) = $R_m C_m$, in msec, where R_m = D.C. resistance of fiber membrane, in ohm-cm², and C_m = membrane capacity = τ / R_m , in $\mu F \cdot cm^{-2}$. R_m also = $r_m \cdot 2\pi a$ (where a = fiber radius). Specific resistance of internal protoplasm (R_i), in ohm-cm, = $r_i \cdot 2\pi a$. Specific resistance of outside fluid (R_o), in ohm-cm, has following values: Woods Hole sea water, 20.9 ohm-cm (25°C); Tyrode's solution, 51 ohm-cm (37°C); frog Ringer's, 94 ohm-cm (18°C), 92 ohm-cm (19°C), 90 ohm-cm (20°C), 83 ohm-cm (22°C); myelin sheath, sciatic nerve, 800 megohm-cm.

Tissue and Property		Value	Tissue and Property		Value
Squid (<i>Loligo forbesi</i>)			Cuttlefish (<i>Sepia officinalis</i>)		
1	Unmyelinated nerves ¹		52	Unmyelinated nerves ²	
2	Fiber diameter, μ	500	53	Fiber diameter, μ	200
3	Resting potential, observed, mV	50	54	Temperature, °C	12-17
4	Action potential, amplitude, mV	90	55	Resting potential after correc. junct. pot., mV	62(53-67)
5	Unmyelinated nerves ¹		56	Action potential ¹³ , amplitude, mV	120
6	Fiber diameter, μ	500	57	Duration, msec	14; 75
7	Resting potential, observed, mV	45	58	Maximum rate of rise, V·sec ⁻¹	840(650-1150)
8	After correction for junction potential, mV	60	59	Conduction speed, m·sec ⁻¹	6.7
9	Action potential, amplitude, mV	90	60	Unmyelinated nerves ²	
10	Unmyelinated nerves ¹		61	Fiber diameter, μ	204(126-306)
11	Fiber diameter, μ	500-700	62	Temperature, °C	12-17
12	Resting potential, observed, mV	48(40-53)	63	Space constant ¹⁴ , mm	5.7(2.0-10.3)
13	After correction for junction potential, mV	62	64	Resistance ¹⁴	
14	Action potential, amplitude, mV	88(82-89)	65	Specific; internal protoplasm, ohm-cm	63(34-105)
15	Maximum rate of rise, V·sec ⁻¹	630	66	D.C.; fiber membrane, ohm-sq cm	9,200(1,400-31,700)
16	Maximum rate of fall, V·sec ⁻¹	380	67	Membrane capacity ¹⁴ , $\mu F \cdot cm^{-2}$	1.17(0.46-3.76)
17	Unmyelinated nerves ²		Lobster (<i>Homarus vulgaris</i>)		
18	Fiber diameter, μ	500-700	68	Unmyelinated nerves	
19	Temperature, °C	20	69	Fiber diameter, μ	75
20	Resting potential after correc. junct. pot., mV	47	70	Resting potential, observed, mV	62
21	Action potential, amplitude, mV	80	71	Action potential ¹³ , amplitude, mV	106
22	Maximum rate of rise, V·sec ⁻¹	500	72	Unmyelinated nerves	
23	Maximum rate of fall, V·sec ⁻¹	301	73	Fiber diameter, μ	75
24	Unmyelinated nerves ³		74	Action potential ¹³ , amplitude, mV	110
25	Fiber diameter, μ	500	75	Unmyelinated nerves	
26	Resting potential, observed, mV	51(46-59)	76	Fiber diameter, μ	75
27	After correction for junction potential, mV	61	77	Temperature, °C	15-20
28	Action potential, amplitude, mV	108(77-168)	78	Space constant ¹⁴ , mm	1.61(0.81-2.95)
29	Unmyelinated nerves ²		79	Resistance ¹⁴	
30	Fiber diameter, μ	400	80	Specific; internal protoplasm, ohm-cm	60.5(43.2-83.6)
31	Temperature, °C	21-28	81	D.C.; fiber membrane, ohm-sq cm	2290(564-7330)
32	Resting potential after correc. junct. pot., mV	48.6(27.5-68)	82	Membrane capacity ¹⁴ , $\mu F \cdot cm^{-2}$	1.3(0.46-3.24)
33	Action potential, amplitude, mV	85.3(46-127)	Crab (<i>Carcinus maenas</i>)		
34	Duration, msec	0.35-0.54; 4.55	83	Unmyelinated nerves	
35	Conduction speed, m·sec ⁻¹	19.2	84	Fiber diameter, μ	25-35
36	Unmyelinated nerves		85	Space constant ¹⁴ , mm	1.98(0.89-2.82)
37	Fiber diameter, μ	500	86	Resistance ¹⁴	
38	Temperature, °C	10	87	Specific; internal protoplasm, ohm-cm	90.0(67.1-115.8)
39	Membrane capacity ⁶ , $\mu F \cdot cm^{-2}$	1.1	88	D.C.; fiber membrane, ohm-sq cm	7,653(2,050-15,600)
40	Unmyelinated nerves		89	Membrane capacity ¹⁴ , $\mu F \cdot cm^{-2}$	1.11(0.62-2.02)
41	Fiber diameter, μ	500	90	Action potential ¹³ , amplitude, mV	116
42	Resistance ⁶	71	91	Unmyelinated nerves	
43	Specific; internal protoplasm, ohm-cm	1.8	92	Fiber diameter, μ	30
44	Membrane capacity ⁶ , $\mu F \cdot cm^{-2}$	1.8	93	Resting potential, observed, mV	71-94
45	Unmyelinated nerves		94	Action potential ¹³ , amplitude, mV	116-153
46	Fiber diameter, μ	500	95	Unmyelinated nerves	
47	Temperature, °C	22-25	96	Fiber diameter, μ	30
48	Space constant, mm	2.3(1.8-3.8)	97	Temperature, °C	21
49	In sea water, mm	6.0(5.0-9.3)	98	Conduction speed, m·sec ⁻¹	3-4
50	Resistance ⁷		Crab (<i>Carcinus maenas</i> and <i>Portunus depurator</i>)		
51	Specific; internal protoplasm, ohm-cm	29	99	Extensor muscle, carapodite ²	
52	D.C.; fiber membrane, ohm-sq cm	700 ⁸ (400-1100)	100	Fiber diameter, μ	100-600 ¹⁵
53	Unmyelinated nerves		101	Temperature, °C	70-500 ¹⁶
54	Fiber diameter, μ	500	102	Space constant ¹⁷ , mm	20
55	Resistance ⁶	<200	103	Resistance ¹⁷	(0.4-2.65)
56	D.C.; fiber membrane, ohm-sq cm	1.8	104	Specific; internal protoplasm, ohm-cm	69
57	Unmyelinated nerves		105	D.C.; fiber membrane, ohm-sq cm	100(20-2000)
58	Fiber diameter, μ	500	106	Membrane capacity ¹⁷ , $\mu F \cdot cm^{-2}$	40
59	Resistance ⁹	23(14.4-40.5)	107	Resting potential after correc. junct. pot., mV	70±0.5 ¹⁸ (56-93)
60	D.C.; fiber membrane, ohm-sq cm	23(14.4-40.5)	108	Action potential, amplitude, mV	61±1.2 ¹⁸ (0-84) ¹⁹
61	Unmyelinated nerves		109	Duration, msec	3.5(2-17)
62	Fiber diameter, μ	500	110	Maximum rate of rise, V·sec ⁻¹	20.5±1
63	Temperature, °C	21-25	111	Conduction speed, m·sec ⁻¹	0.3
64	Conduction speed ¹² , m·sec ⁻¹	34.8; 31.1; 29.2	112	Locust (<i>Locusta migratoria migratorioides</i> R. and F.) and Cockroach (<i>Periplaneta americana</i> L.)	
65	Unmyelinated nerves		113	Extensor tibialis muscle, metathoracic leg ²	
66	Fiber diameter ¹² , μ	527; 463; 426	114	Resting potential after correct.junct. pot., mV	60
67	Temperature, °C	21-25	115	Action potential amplitude, mV	60-75
68	Conduction speed ¹² , m·sec ⁻¹	34.8; 31.1; 29.2	116		

/1/ Solution in internal electrode used to depolarize: sea-water. /2/ Solution in internal electrode used to depolarize: 3M KCl. /3/ Solution in internal electrode used to depolarize: isotonic KCl. /4/ Spike. /5/ Positive after-phase. /6/ Determined by alternating current and transverse electrodes. /7/ Resistance length measurements made with direct current. /8/ 1000 ohm-cm² adopted as best value. (Value for axons in better physiological condition.) /9/ Determined by direct current pulses and internal electrodes. /10/ Determined by alternating current and longitudinal electrodes. /11/ Assuming membrane capacity=1.1. /12/ Passing from the proximal to the distal end of the giant axon. /13/ Determined by external electrodes. /14/ Determined by direct current pulses and longitudinal electrodes. /15/ *Carcinus maenas*. /16/ *Portunus depurator*. /17/ Determined by square wave pulses and internal electrodes. /18/ Standard error of mean. /19/ Value of zero omitted in averaging.

280. ELECTRO-PHYSIOLOGICAL PROPERTIES, EXCITABLE TISSUES: ANIMALS (Continued)

Tissues and Property		Values	Tissues and Property		Values
Locust (<i>Locusta migratoria migratorioides</i> R. and F.) and Cockroach (<i>Periplaneta americana</i> L.) (concluded)			Frog, bull (<i>Rana catesbeiana</i>)		
102	Maximum rate of rise, V·sec ⁻¹	1720	156	Sciatic nerve	
103		3621		Conduction speed, m·sec ⁻¹	32-46
104	End-plate potential, rate of rise, V·sec ⁻¹	1420	Frog (<i>Rana pipiens</i>)		
105		3821		Myelinated fiber ² ; sciatic nerve ²	
Eel, electric (<i>Electrophorus electricus</i> L.)			157	Fiber diameter ²⁸ , μ	7-22
106	Electroplates ²		158	Resting potential, observed, mV	60-80
107	Fiber diameter ²² , μ	100	159	Action potential, amplitude, mV	100-130
	Temperature, °C	24-25	160	Conduction speed, m·sec ⁻¹	14-43
	Resistance ⁹		Sartorius muscle ^{2, 3}		
108	Specific; internal protoplasm, ohm·cm	50	161	Temperature, °C	20-22
109	D.C.; fiber membrane, ohm·sq cm	10 ²³	162	Resting potential, observed, mV	78.4±5.3
110		0.23 ²⁴	163	After correction for junction potential, mV	97.6±5.7
111	Resting potential after correc. junct. pot. ²⁵ , mV	84	164	End-plate ³⁰ , sartorius muscle ²	
112	Action potential, amplitude ²⁶ , mV	151	165	Temperature, °C	22-23
113	Duration, msec	2.3	166	Resting potential after correc. junct. pot. ³¹ , mV	94.6±0.8
114	Conduction speed, m·sec ⁻¹	1.7	167	Action potential, amplitude ³¹ , mV	120.9±1.5
			168	Maximum rate of rise ³¹ , V·sec ⁻¹	670±22
Electroplates ²			169	End-plate ³⁰ , sartorius muscle ²	
115	Temperature, °C	22-24	170	Temperature, °C	22-23
116	Resting potential after correc. junct. pot., mV	73.1±4.76	171	Resting potential after correc. junct. pot. ³² , mV	94.9±0.9
117	Action potential, amplitude, mV	126±15.55	172	Action potential, amplitude ³² , mV	117.4±1.4
118	Duration, msec	2.16±0.55	173	Maximum rate of rise ³² , V·sec ⁻¹	750±31
119	Conduction speed, m·sec ⁻¹	1.05(0.71-1.59)		End-plate ³² , sartorius muscle ²	
Spinal nerves			174	Temperature, °C	
120	Temperature, °C	24	175	Resting potential after correc. junct. pot. ³³ , mV	92.8±0.5
121	Conduction speed, m·sec ⁻¹	13-17	176	Action potential, amplitude ³³ , mV	130.8±0.5
Lateral nerves			177	Maximum rate of rise ³³ , V·sec ⁻¹	650±25
122	Temperature, °C	24		Ventricle ²	
123	Conduction speed, m·sec ⁻¹	25	178	Temperature, °C	12-16
Spinal cord			179	Resting potential after correc. junct. pot., mV	62(50-90)
124	Temperature, °C	24	180	Action potential, amplitude, mV	80.8(65-115)
125	Conduction speed, m·sec ⁻¹	44-50	181	Duration ³⁴ , msec	(400-1000)
Chick Embryo			182	Ventricle ²	
126	Resting potential after correc. junct. pot., mV	29.2±1.3(10-41)	183	Temperature, °C	19
127	Action potential, amplitude, mV	39.2±2.0(11-81)	184	Resting potential after correc. junct. pot., mV	64.5±17.5
Ventricle			185	Action potential, amplitude, mV	77.2±22.3
128	Resting potential after correc. junct. pot., mV	39.3±0.7(10-70)	186	Duration, msec	8-25735
129	Action potential, amplitude, mV	53.5±1.4(13-100)	187	Maximum rate of rise, V·sec ⁻¹	10
Toad (<i>Bufo bufo</i>)			188	Maximum rate of fall ³⁴ , V·sec ⁻¹	0.8
			189	Ventricle ²	
Tactile fibers			190	Temperature, °C	22-29
130	Fiber diameter, μ	8-15	191	Resting potential after correc. junct. pot., mV	54±8(40-80)
131	Temperature, °C	22-26	192	Action potential, amplitude, mV	74.9±9(50-110)
132	Conduction speed, m·sec ⁻¹	20-35	193	Duration ³⁴ , msec	420-1000
Pressure fibers				Frog (<i>Rana temporaria</i>)	
133	Fiber diameter, μ	4-5	190	Sartorius muscle ²	
134	Temperature, °C	22-26	191	Fiber diameter, μ	80
135	Conduction speed, m·sec ⁻¹	5-8	192	Temperature, °C	18
Nociceptive nerve, large			193	Resting potential, observed, mV	88
136	Fiber diameter, μ	6-9	194	After correction for junct. potential, mV	88
137	Temperature, °C	22-26	195	Action potential, amplitude, mV	119
138	Conduction speed, m·sec ⁻¹	10-15	196	Duration, msec	1.54; 436
Nociceptive nerve, small			197	Maximum rate of rise, V·sec ⁻¹	470
139	Fiber diameter, μ	3-5	198	Maximum rate of fall, V·sec ⁻¹	86
140	Temperature, °C	22-26	199	Sartorius muscle ^{37, 2}	
141	Conduction speed, m·sec ⁻¹	3-9	200	Fiber diameter ³⁸	137
Unmyelinated nerves			201	Temperature, °C	19-20
142	Fiber diameter, μ	<2	202	Space constant ³⁹ , mm	2.4(2.2-2.6)
143	Temperature, °C	22-26	203	Resistance ³⁹	
144	Conduction speed, m·sec ⁻¹	1.0-0.1	204	Specific; internal protoplasm, ohm·cm	25040
Frog			205	D.C.; fiber membrane, ohm·sq cm	4100
145	Motor fibers, isolated ²⁷		206	Membrane capacity ³⁹ , μ F·cm ⁻²	8
	Resting potential after correc. junct. pot., mV	71	207	Resting potential after correc. junct. pot., mV	88±0.6
146	Ventral root fibers, small diameter ²⁸		208	Action potential, amplitude, mV	123±1
	Conduction speed, m·sec ⁻¹	2-8	209	Conduction speed, m·sec ⁻¹	1.4
147	Ventral root fibers, large diameter ²⁹			Sartorius muscle ²	
	Conduction speed, m·sec ⁻¹	8-40	210	Fiber diameter ³⁸ , μ	137
148	Sciatic nerve (stripped of epineurium)		211	Temperature, °C	19-20
	Space constant, mm	2.8	212	Space constant ⁴¹ , mm	2.4; 2.15
149	Sartorius muscle ¹		213	Resistance ⁴¹	
	Resting potential after correc. junct. pot., mV	72(max 90)	214	Specific; internal protoplasm, ohm·cm	25040
150	Iliofibularis muscle ²		215	D.C.; fiber membrane, ohm·sq cm	3300; 4100
	Resting potential after correc. junct. pot., mV	90	216	Membrane capacity ⁴¹ , μ F·cm ⁻²	6.5
151	Action potential, amplitude, mV	120		Sartorius muscle ²	
152	Ventricle ²		213	Resting potential after correc. junct. pot., mV	88.1-0.6
	Resting potential after correc. junct. pot., mV	64.34±12		Sartorius muscle	
153	Action potential, amplitude, mV	84.44±10.9	214	Fiber diameter ³⁸ , μ	129
154	Ventricle ²		215	Temperature, °C	20
	Resting potential after correc. junct. pot., mV	64.5±2.7(27-112)	216	Space constant ⁴⁷ , mm	1.6
155	Action potential, amplitude, mV	72.2±2.9(30-132)			

/2/ Solution in internal electrode used to depolarize: 3M KCl. /3/ Solution in internal electrode used to depolarize: isotonic KCl. /4/ Spike. /9/ Determined by direct current pulses and internal electrodes. /17/ Determined by square wave pulses and internal electrodes. /20/ Locust. /21/ Cockroach. /22/ Ant.-post. direction, or non-nervous to nervous face. /23/ Nervous face. /24/ Non-nervous face. /25/ Across each face of electroplate. /26/ Electrode penetrating nervous face. /27/ Potentiometric method. /28/ Innervate slow muscle fiber system. /29/ Innervate twitch muscle fiber system. /30/ Max. rate of rise of end-plate potential, 220 V·sec⁻¹. /31/ End-plate center. /32/ 35 μ from end-plate center. /33/ Distant from end-plate. /34/ Depends on cycle length. /35/ Temp. range, 30-0.2°C. /36/ Calculated on basis of conduction speed in m·sec⁻¹ being twice fiber diameter in micra. /37/ End-plate response during normal impulse transmission reaches 40 mV in first 0.5 sec. /38/ Calculated from fiber diameter = $\sqrt{(4\pi R_1/R_2)}$. /39/ Determined by square wave pulses and longitudinal electrodes. /40/ Assumed. /41/ Determined by end-plate potential and internal electrodes.

280. ELECTRO-PHYSIOLOGICAL PROPERTIES, EXCITABLE TISSUES: ANIMALS (Concluded)

Tissue and Property		Value	Tissue and Property		Value
Frog (<i>Rana temporaria</i>) (concluded)			Dog (<i>Canis familiaris</i>)		
Sartorius muscle ¹⁷			Purkinje fibers, ventricle ²		
217	D.C.; fiber membrane, ohm·sq cm	2064	269	Fiber diameter, μ	30
218	Membrane capacity ¹⁷ , $\mu\text{F}\cdot\text{cm}^{-2}$	10.6	270	Temperature, $^{\circ}\text{C}$	37-38
End-plate, sartorius muscle ²			271	Resting potential after correc. junct. pot., mV	90±6 121
219	Temperature, $^{\circ}\text{C}$	20	272	Action potential, amplitude, mV	240-400
220	Resting potential after correc. junct. pot., mV	90(75-107)	273	Duration ⁴ , msec	500-1000
Bundles, adductor magnus			274	Maximum rate of rise, $\text{V}\cdot\text{sec}^{-1}$	2±0.5
221	Fiber diameter, μ	75(30-130)	275	Conduction speed, $\text{m}\cdot\text{sec}^{-1}$	2±0.5
222	Temperature, $^{\circ}\text{C}$	22.5	Purkinje fibers, ventricle ²		
223	Space constant ¹⁴ , mm	0.65(0.47-1.15)	276	Temperature, $^{\circ}\text{C}$	38-40
Resistance ¹⁴			277	Resting potential after correc. junct. pot., mV	89±3.2 121±4
224	Specific; internal protoplasm, ohm·cm	176(131-280)	278	Action potential, amplitude, mV	500
225	D.C.; fiber membrane, ohm·sq cm	1500(650-4500)	279	Duration ⁴⁴ , msec	2.5
226	Membrane capacity ¹⁴ , $\mu\text{F}\cdot\text{cm}^{-2}$	6(4.5-10)	Ventricle ²		
Extensor muscle, dig. IV			281	Resting potential after correc. junct. pot., mV	90
227	Fiber diameter, μ	43	282	Action potential, amplitude, mV	120-130
228	Temperature, $^{\circ}\text{C}$	22.5	Ventricle ²		
229	Space constant ¹⁴ , mm	1.1(0.75-1.53)	283	Resting potential after correc. junct. pot., mV	80.7±7(65-95)
Resistance ¹⁴			284	Action potential, amplitude, mV	100±8(80-120)
230	Specific; internal protoplasm, ohm·cm	255(206-355)	Auricle ²		
231	D.C.; fiber membrane, ohm·sq cm	4300(1500-9500)	285	Resting potential after correc. junct. pot., mV	85±9
232	Membrane capacity ¹⁴ , $\mu\text{F}\cdot\text{cm}^{-2}$	4.4(2.9-5.9)	286	Action potential, amplitude, mV	100±1
Cells, spinal ganglion			Auricle ²		
233	Fiber diameter, μ	80-90	287	Temperature, $^{\circ}\text{C}$	37-38
234	Resting potential, observed, mV	50-90	288	Resting potential after correc. junct. pot., mV	85
235	Action potential, amplitude, mV	50-90	289	Action potential, amplitude, mV	105
Frog (<i>Rana temporaria</i>) and Cat (<i>Felis catus</i>)			290	Duration ⁴⁵ , msec	150-250
Myelinated root fibers ²			291	Conduction speed, $\text{m}\cdot\text{sec}^{-1}$	1
236	Resting potential, observed, mV	85-95	Papillary muscle ²		
Cat (<i>Felis catus</i>)			292	Temperature, $^{\circ}\text{C}$	37-38
Motor neurones, spinal cord ²			293	Resting potential after correc. junct. pot., mV	85
237	Fiber diameter, μ	100	294	Action potential, amplitude, mV	105
238	Temperature, $^{\circ}\text{C}$	37	295	Duration ⁴⁵ , msec	150-250
239	Resting potential after correc. junct. pot., mV	70	296	Conduction speed, $\text{m}\cdot\text{sec}^{-1}$	1
240	Action potential, amplitude, mV	(90-100)	Calf and Sheep		
241	Duration, msec	(300-500)	Purkinje fibers, ventricle ²		
242	Maximum rate of rise, $\text{V}\cdot\text{sec}^{-1}$	(200-250)	297	Temperature, $^{\circ}\text{C}$	38
Auricle ²			Resistance ¹⁷		
243	Fiber diameter, μ	30	298	Specific; internal protoplasm, ohm·cm	154
244	Temperature, $^{\circ}\text{C}$	36-38	299	D.C.; fiber membrane, ohm·sq cm	1220
245	Resting potential after correc. junct. pot., mV	60.4±4.68 (36-91)	300	Membrane capacity ¹⁷ , $\mu\text{F}\cdot\text{cm}^{-2}$	11.3
246	Action potential, amplitude, mV	65.2±7.67	301	Resting potential after correc. junct. pot., mV	94
247	Maximum rate of rise, $\text{V}\cdot\text{sec}^{-1}$	10	302	Action potential, amplitude, mV	129
248	Maximum rate of fall ³⁴ , $\text{V}\cdot\text{sec}^{-1}$	0.8-2	Goat (<i>Capra hircus</i>)		
249			Purkinje fibers, ventricle		
Cat			303	Fiber diameter ⁴⁶ , μ	75
250	Sartorius muscle ² ; vastus m. ²	20	304	Temperature, $^{\circ}\text{C}$	37
251	Fiber diameter, μ	116	305	Space constant, mm	1.9
252	Resting potential after correc. junct. pot., mV	79.5±5.7	Resistance ¹⁷		
253	Action potential, amplitude, mV	121	306	Specific; internal protoplasm, ohm·cm	105
254	Duration, msec	142	307	D.C.; fiber membrane, ohm·sq cm	1940(760-3380)
255	Maximum rate of rise, $\text{V}\cdot\text{sec}^{-1}$	730	308	Membrane capacity ¹⁷ , $\mu\text{F}\cdot\text{cm}^{-2}$	12.4
Guinea Pig			309	Conduction speed, $\text{m}\cdot\text{sec}^{-1}$	2.2±0.5
256	Sartorius muscle ² ; pectoralis major ² ; biceps m. ²	20	Purkinje fibers, ventricle ²		
257	Fiber diameter, μ	84.5±5.7	310	Fiber diameter, μ	40-100
258	Resting potential after correc. junct. pot., mV	121	311	Temperature, $^{\circ}\text{C}$	37
259	Action potential, amplitude, mV	142, 1-6 ³⁶	312	Resting potential after correc. junct. pot., mV	94±8
260	Duration, msec	730	313	Action potential, amplitude, mV	135
261	Maximum rate of rise, $\text{V}\cdot\text{sec}^{-1}$	160	Man (<i>Homo sapiens</i>)		
Taenia coli ² ; longitudinal smooth muscle ²			Ulnar nerve (most rapidly conducting fibers to muscles of hypthenar eminence)		
262	Fiber diameter, μ	<10	Conduction speed, $\text{m}\cdot\text{sec}^{-1}$		
263	Resting potential after correc. junct. pot. ⁴³ , mV	60±9.18	314		57 ⁴⁷
Rabbit			Mammalia		
Smooth muscle, sphincter pupillae ²			Myelinated nerve fibers		
264	Fiber diameter, μ	<10	315	Fiber diameter, μ	1-20
265	Temperature, $^{\circ}\text{C}$	35	316	Conduction speed, $\text{m}\cdot\text{sec}^{-1}$	5-120
266	Resting potential after correc. junct. pot. ⁴⁴ , mV	60	Myelinated nerve fibers (preganglionic, autonomic)		
Mouse, white			317	Fiber diameter, μ	<3
Anterior tibialis muscle ²			318	Conduction speed, $\text{m}\cdot\text{sec}^{-1}$	3-15
267	Temperature, $^{\circ}\text{C}$	24-30	Unmyelinated nerve fibers (somatic, autonomic)		
268	Resting potential after correc. junct. pot., mV	99.8±6.5	319	Conduction speed, $\text{m}\cdot\text{sec}^{-1}$	0.6-2

/2/ Solution in internal electrode used to depolarize: 3M KCl. /14/ Determined by direct current pulses and longitudinal electrodes. /17/ Determined by square wave pulses and internal electrodes. /34/ Depends on cycle length. /36/ Calculated on basis of conduction speed in $\text{m}\cdot\text{sec}^{-1}$ being twice fiber diameter in micra. /38/ Calculated from fiber diameter = $\sqrt{(4\pi \times R_i/r_i)}$. /42/ With negative after potential of 1-6 msec; value of negative after-potential varies from 5-28 mV. /43/ At in situ length; membrane potential varies inversely with length. /44/ No spontaneous movements; cf Fn 43. /45/ At heart rates of 130-150 beats per min. /46/ May vary 1.8 times over same fiber. /47/ Varies with age.

281. MUSCLE: PHYSICAL PROPERTIES

When a muscle is stimulated, after a brief latent period, the contractile substance shortens against a force P with a velocity v . When shortening is prevented, it exerts a maximum force P_0 ; when shortening is unrestrained, no force is exerted and it shortens at a maximum velocity v_0 . P_0 is often expressed as the force per unit area of muscle cross section (P_0/S) and v_0 in muscle lengths per sec. Experimentally it is found in all muscles studied that P and v can be related by an equation of the form $(P + a)(v + b) = b(P_0 + a)$, where " b " is a constant and has the dimensions of velocity, and " a " the shortening heat constant with the dimensions of force (cf Part II, Item 15). a/P_0 is approximately $1/4$ and largely independent of temperature. The contractile material of muscle is in series with an elastic component which must be stretched before external tension is manifest. This takes time and, in a single muscle twitch, relaxation usually sets in before P_0 can be reached. The ratio of the peak twitch tension to P_0 is called the twitch/tetanus ratio, and the time after the stimulus at which the peak tension is reached is known as the contraction time. The velocity of the action potential provides an index to the way in which the process of contraction spreads from the active to the inactive parts of the muscle. Resting muscle gives out a small amount of heat as a result of its metabolism. During activity the rate of heat production is much greater. The initial heat has two components: maintenance or activation heat produced when the contractile machinery is activated; and shortening heat, produced in addition in proportion to the shortening of the muscle. For a long time after activity the rate of heat production is slightly greater than the resting rate. The total amount of heat is the recovery heat.

Part I: MECHANICAL CHARACTERISTICS

Species	Muscle	Temp °C	Latency msec		P_0/S kg/sq cm	a/P_0	Ratio: Twitch Tetanus	Contract. Time msec	Velocity	
			I ¹	II ²					Action Potential cm/sec	Max. of shorten. lengths/sec ³
1 Man	Flexors of elbow	37			2.4	0.36		70-80	400	6
2 Cat	Soleus	34-37		10			0.3	100		
3	Gastrocnemius	34-37		6.5			0.3	40		
4	Internal rectus	34-37					0.09	7.5-10		
5	Nictitating membrane			144 ⁴				800-1900	50-80	
6 Rabbit	Glycerol extracted fiber ⁵	20			1-4	0.1				0.2
7 Rat	Diaphragm	37	1.0	1.5	1.6	0.25	0.14	16	500	11
8 Fowl	Gastrocnemius	36					0.13	50		
9 Tortoise	Retractor penis ⁶	0		70	2.5	0.28		4000		0.1
10 Frog	Sartorius	20-22	1.5	2.9	2.1	0.18	0.22	25	160	10
11	Sartorius	0	7.1	15	1.7	0.25	0.72	400	55	2
12	Semimembranosus, single fibers	18-26			3.3			70		9.2
13	Semimembranosus, single fibers	0			2.8	0.16		400		3.0
14 Toad	Sartorius and semimembranosus	0	9.5	20	1.2	0.3		800	80	0.8
15 Dogfish and ray	Coracohyoid, coracomandibula	0			0.6	0.35		200	65	2.0
16 Snail	Pharyngeal retractor	15			5	0.28		300		0.15
17 Mytilus	Anterior byssal retractor	14		50	3.5	0.16	0.13		17.6	0.06
18	Pedal retractor	14		20	2.5	0.1	0.33			0.06
19 Sea anemone	Wall muscle			10,000	40			40,000		

/1/ From stimulus to beginning of early tension relaxation. /2/ From stimulus to beginning of development of positive tension or shortening. /3/ Maximum velocity of shortening. Muscle lengths/sec. /4/ Includes conduction time and neuromuscular delay. /5/ Activated by ATP. /6/ And ileofibularis.

Part II: MISCELLANEOUS PROPERTIES OF FROG MUSCLE

Property		Value	Property		Value
1	Density, g/cu cm	1.062	9	Active state, time to fall to 50%, 0°C, ($Q_{10} \approx 2$), msec	250
2	Diffusion constant of oxygen, at 20°C, ml/min for 1 sq cm area, 1 μ thickness; 760 mm/Hg pressure difference	0.14	10	Series elastic component, stretch produced by maximum tetanic tension, % of muscle length	4
3	Thermal conductivity, cal/min for 1 sq cm area, 1 cm thickness; 1°C temperature difference	1.18×10^{-3}	11	Membrane potential, 17.4°C, mV	90
4	Volume coefficient of thermal expansion, (unloaded, resting), ml/ml \times °C	0.16×10^{-3}	12	Action potential, 17.4°C, mV	124
5	Linear coefficient of thermal expansion, (unloaded, resting), cm/cm \times °C	$(-0.1 \text{ to } 0.6) \times 10^{-3}$	13	Resting heat ¹ , cal/g \times minutes	3.75×10^{-3}
6	Temperature coefficient of resting tension, (small tensions), dyne/dyne \times °C	$(2.4 - 6) \times 10^{-3}$	14	Initial heat ¹ : Maintenance, cal/g \times seconds	2.3×10^{-3}
7	Latency relaxation, maximum drop in tension, % of tetanic tension	0.1	15	Initial heat ¹ : Shortening, cal/cm shortening \times sq cm (equals " a " of Part I, if expressed in force units)	8.2×10^{-3}
8	Active state, duration of plateau, °C, ($Q_{10} = 2.20$), msec	35	16	Recovery heat ¹ , total energy developed by contraction initial energy developed	2
			17	Maximum efficiency ¹ , work done \times 100 energy consumed	20

/1/ Sartorius, 0°C.

Part III: MICROSCOPIC STRUCTURE AND BIREFRINGENCE CHARACTERISTICS OF MUSCLE

Species	Muscle	Conditions	Myofibril ¹ Diameter μ	Protofibril ¹ Diameter μ	Lengths of A ² and J ³ Bands								Birefringence	
					At Rest ⁴				Contraction ⁵				At Rest $\times 10^{-3}$	Contraction ⁶ Decrease % of Rest
					A μ	J μ	A+J μ	(A/A+J) $\times 100$	A μ	J μ	A+J μ	(A/A+J) $\times 100$		
1 Dog	Sartorius	Living fibers											2.60	
2 Guinea pig	Gluteus maximus ⁷	Single fiber, static			1.41	0.84	2.25	62.7	1.20	1.06	2.26	53.1	1.98	
3 Mouse	Rectus abdominis	Living, whole muscle											2.61	
4 Rabbit	Psoas		0.8-1.8	200										
5	Leg muscle		0.5-1.0	50-250										
6 Lizard	Thoracalis abdominis				1.34	0.90	2.24	59.9						
7 Toad	Leg muscle		1.0	160										
8 Frog	Semitendinosus ⁸	Living fiber	0.5-1.0	50-250	1.37	0.81	2.18	62.9	1.13	1.05	2.18	51.9	2.0 ⁹	20-30
9	Gastrocnemius	Static		40										
10	Sartorius ¹⁰	Whole muscle static											2.07	12-14
11 Crayfish	Leg flexor				3.5	2.8	6.3	55.5						
12 Crab	Leg flexor				3.4	2.6	6.0	56.6	3.2	2.9	6.1	52.5		

/1/ Composed of filaments denoted as protofibrils. /2/ Anisotropic. /3/ Isotropic. /4/ Equilibrium length (at which tension = 0.5% of maximum tension in isometric tetanic contraction. /5/ Isometric tetanic contraction, equilibrium length. /6/ Isometric. /7/ 37°C. /8/ 17-20°C. /9/ Corrected for deviation from circular X-section by adding 18.5%. Birefringence increases with decreasing temperature by 0.5%/°C. /10/ 0°C.

282. MUSCLES: MAN

Table represents an abridged listing of muscles. In no case is a complete atlas intended.

Ant. = anterior; ext. = external; inf. = inferior; int. = internal; lat. = lateral; med. = medial; post. = posterior; trans. = transverse; vert. = vertebra(e); cart. = cartilage.

Muscle	Origin	Insertion	Action
1 Abductor digiti quinti (hand)	Pisiform; flexor carpi ulnaris tendon.	Med. surface base proximal phalanx little finger.	Abducts little finger.
2 Abductor digiti quinti (foot)	Med. and lat. tubercles calcaneus; plantar fascia.	Lat. surface base proximal phalanx little toe.	Abducts little toe.
3 Abductor hallucis	Med. tubercle calcaneus; plantar fascia.	Med. surface base proximal phalanx great toe.	Abducts, flexes great toe.
4 Abductor pollicis brevis	Navicular; ridge greater multangular; trans. carpal ligament.	Lat. surface base proximal phalanx thumb.	Abducts thumb.
5 Abductor pollicis longus	Posterior surfaces radius and ulna.	Radial side base 1st metacarpal bone.	Abducts, extends thumb.
6 Adductor brevis	Outer surface inferior ramus of pubis.	Upper part of linea aspera of femur.	Adducts, rotates, flexes thigh.
7 Adductor hallucis	Plantar fascia; base 2nd, 3rd, 4th metatarsals.	Lat. side base proximal phalanx great toe.	Adducts great toe.
8 Adductor longus	Crest, symphysis of pubis.	Linea aspera of femur.	Adducts, rotates, flexes thigh.
9 Adductor magnus	Inf. ramus pubis; ramus ischium.	Linea aspera of femur.	Adducts thigh.
	Ischial tuberosity.	Adductor tubercle of femur.	Extends thigh.
10 Adductor minimus	Sup. portion adductor magnus.	Ischium; body, ramus of pubis.	Adducts thigh.
11 Adductor pollicis	Multangular; capitate; bases 2nd, 3rd, 4th metacarpals.	Med. aspect base proximal phalanx of thumb.	Adducts, opposes thumb.
12 Anconeus	Back lat. epicondyle of humerus.	Olecranon; dorsal surface of ulna.	Extends forearm.
13 Arrectores pilorum	Papillary skin layer.	Hair follicles.	Elevates skin hairs.
14 Articularis genu	Distal 4th anterior surface of femur.	Synovial membrane of knee joint.	Lifts capsule of knee joint.
15 Aryepiglotticus	Apex arytenoid cartilage.	Lateral margin epiglottis.	Closes larynx inlet.
16 Arytenoideus, obliquus	Base muscular process arytenoid cartilage.	Apex opposite arytenoid cartilage.	Closes larynx inlet.
17 transversus	Base muscular process arytenoid cartilage.	Continuous with thyroarytenoid, base opposite cart.	Approximates arytenoid cartilages.
18 Auricularis, anterior	Superficial temporal fascia.	Cartilage of ear.	Draws ear pinna forward.
19 posterior	Mastoid process.	Cartilage of ear.	Draws pinna backward.
20 superior	Galea aponeurotica.	Cartilage of ear.	Raises ear pinna.
21 Biceps brachii	Tip coracoid process scapula; supraglenoid tuberosity.	Radius tubercle; forearm deep fascia.	Flexes forearm, supinates hand.
22 Biceps femoris	Linea aspera of femur; ischial tuberosity.	Head fibula; lat. condyle tibia; deep fascia lat. knee.	Flexes knee joint, extends hip.
23 Brachialis	Anterior aspect humerus.	Coronoid process of ulna.	Flexes forearm.
24 Brachioradialis	External supracondyloid ridge of humerus.	Lower end of radius.	Flexes forearm.
25 Buccinator	Alveolar processes maxilla, mandible, pterygomandibular raphe.	Orbicularis oris at angle of mouth.	Compresses cheek, retracts mouth.
26 Bulbocavernosus	Central point perineum; median raphe of bulb.	Fascia of penis (clitoris).	Constricts bulbous urethrae.
27 Caninus	Canine fossa of maxilla.	Orbicularis oris; skin at angle of mouth.	Raises angle of mouth.
28 Chondroglossus	Inner side, base lesser cornu of hyoid bone.	Substance of tongue.	Depresses, retracts tongue.
29 Ciliaris	Scleral spur; sphincter of ciliary body.	Ciliary process.	Visual accommodation.
30 Coccygeus	Ischial spine; sacrospinous ligament.	Lat. border lower sacrum; upper coccyx.	Supports, raises coccyx.
31 Constrictor pharyngis, inf.	Under surfaces cricoid and thyroid cartilages.	Med. raphe posterior wall of pharynx.	Constricts pharynx.
32 medius	Cornua of hyoid; stylohyoid ligament.	Middle of posterior wall of pharynx.	Constricts pharynx.
33 superior	Med. pterygoid lamina; pterygomandibular raphe.	Posterior median raphe.	Constricts pharynx.
34 Coracobrachialis	Coracoid process of scapula.	Medial aspect shaft of humerus.	Flexes, adducts arm.
35 Corrugator cutis ani	Submucous tissue within anus.	Skin surrounding anus.	Corrugates skin around anus.
36 Corrugator supercilii	Superciliary arch of frontal bone.	Skin of forehead.	Moves eyebrows; wrinkles forehead.
37 Cremaster	Inferior margin internal oblique muscle of abdomen.	Pubic tubercle.	Elevates testis.
38 Crico-arytenoideus, lateralis	Lateral surface cricoid cartilage.	Muscular process arytenoid cartilage.	Approximates vocal folds.
39 posterior	Back of cricoid cartilage.	Muscular process arytenoid cartilage.	Separates vocal folds.
40 Cricothyroideus	Front, side of cricoid cartilage.	Lamina of thyroid cartilage.	Tenses vocal cords.
41 Deltoides	Clavicle, acromion, spine of scapula.	Deltoid tuberosity of humerus.	Abducts, flexes, extends arm.
42 Depressor alae nasi	Incisor fossa of maxilla.	Ala and septum of nose.	Contracts nostril; depresses ala.
43 Diaphragma	Xiphoid process; costal cartilages; lumbar vertebrae.	Central tendon.	Respiration and expulsive acts.
44 Digastricus, anterior belly	Inner surface mandible near symphysis.	Hyoid bone; intermediate tendon.	Elevates hyoid bone, lowers jaw.
45 posterior belly	Mastoid notch.	Hyoid bone; intermediate tendon.	Elevates hyoid bone, lowers jaw.
46 Epicranius (frontalis et occipitalis)	Forehead skin, occipital bone.	Galea aponeurotica.	Raises eyebrows; draws scalp backward.
47 Extensor carpi radialis brevis	External epicondyle of humerus.	Base 3rd metacarpal bone.	Extends, abducts wrist joint.
48 longus	External supracondyloid ridge of humerus.	Base 2nd metacarpal.	Extends, abducts wrist joint.
49 Extensor carpi ulnaris	External epicondyle of humerus.	Base 5th metacarpal bone.	Extends, adducts wrist joint.
50 Extensor digiti quinti proprius	External epicondyle of humerus.	Dorsum proximal phalanx of little finger.	Extends little finger.
51 Extensor digitorum brevis	Dorsal surface of calcaneus.	Extensor tendons 1st, 2nd, 3rd, 4th toes.	Extends toes.
52 communis	Lateral epicondyle of humerus.	Common extensor tendon of each finger.	Extends wrist joint and phalanges.
53 longus	Ant. fibula; lat. condyle tibia; interosseous membrane.	Common extensor tendons 4 lateral toes.	Extends toes.
54 Extensor hallucis longus	Front of tibia; interosseous membrane.	Base of terminal phalanx of great toe.	Dorsiflexes ankle joint; extends toe.
55 Extensor indicis proprius	Dorsal surface of ulna.	Common extensor tendon of index finger.	Extends index finger.
56 Extensor pollicis brevis	Dorsal surface radius and interosseous membrane.	Dorsal surface proximal phalanx of thumb.	Extends thumb.
57 Extensor pollicis longus	Dorsal surface ulna and interosseous membrane.	Dorsal surface distal phalanx of thumb.	Extends, abducts thumb.
58 Flexor carpi radialis	Medial epicondyle of humerus.	Base 2nd metacarpal.	Flexes, abducts wrist joint.
59 Flexor carpi ulnaris	Medial epicondyle humerus; medial border ulna.	Pisiform; hamulus of hamate; proximal end 5th metacarpal.	Flexes, adducts wrist joint.

60	Flexor digiti quinti brevis (foot)	Base 5th metatarsal; plantar fascia.	Lateral aspect base proximal phalanx little toe.	Flexes little toe.
61	Flexor digiti quinti brevis (hand)	Hamulus of hamate; transverse carpal ligament.	Medial side proximal phalanx little finger.	Flexes little finger.
62	Flexor digitorum brevis	Medial tuberosity calcaneus; plantar aponeurosis.	Four tendons to middle phalanx of 4 lateral toes.	Flexes toes.
63	Flexor digitorum longus	Shaft of tibia, posterior surface.	Distal phalanges lesser toes.	Flexes toes; extends foot.
64	Flexor digitorum profundus	Shaft of ulna; coronoid process.	Distal phalanges of fingers.	Flexes distal phalanges.
65	Flexor digitorum sublimis	Med. epicondyle humerus; coronoid process ulna; ant. margin of radius.	Four tendons to base of middle phalanx of each finger.	Flexes middle phalanges.
66	Flexor hallucis brevis	Under surface cuboid; 3rd cuneiform.	Base proximal phalanx of great toe.	Flexes great toe.
67	Flexor hallucis longus	Posterior aspect of fibula.	Base of distal phalanx great toe.	Flexes great toe.
68	Flexor pollicis brevis	Transverse carpal ligament; ridge great multangular.	Base proximal phalanx of thumb.	Flexes thumb.
69	Flexor pollicis longus	Volar surface radius; coronoid process of ulna.	Base distal phalanx of thumb.	Flexes thumb.
70	Frontalis	Anterior portion of Epicranius; skin of forehead.	Galea aponeurotica.	Draws scalp forward, raises eyebrows.
71	Gastrocnemius	Lateral and medial condyles of humerus.	Posterior surface of calcaneus via tendo calcaneus (tendon of Achilles).	Plantar flexes ankle joint. Flexes knee joint.
72	Gemellus inferior	Tuberosity of ischium.	Greater trochanter of femur.	Rotates thigh laterally.
73	Gemellus superior	Spine of ischium.	Greater trochanter of femur.	Rotates thigh laterally.
74	Genioglossus	Mental spine of mandible.	Hyoid bone; under surface of tongue.	Protrudes and depresses tongue.
75	Geniohyoideus	Mental spine of mandible.	Body of hyoid.	Elevates, draws hyoid forward.
76	Glossopalatinus	Under surface soft palate.	Side of tongue.	Elevates tongue; constricts fauces.
77	Gluteus maximus	Lat. surface ilium; post. surface sacrum, coccyx; sacrotuberous ligament.	Gluteal tuberosity of femur; iliotibial tract.	Extends, abducts, rotates thigh outward.
78	Gluteus medius	Lateral surface of ilium.	Greater trochanter.	Abducts femur.
79	Gluteus minimus	Lateral surface of ilium.	Greater trochanter.	Abducts, medially rotates femur.
80	Gracilis	Inferior ramus of pubis.	Medial surface of tibia.	Adducts femur; flexes knee joint.
81	Hyoglossus	Body, greater cornu of hyoid bone.	Side of tongue.	Depresses tongue.
82	Iliacus	Iliac fossa and sacrum.	Lesser trochanter.	Flexes thigh, trunk on extremity.
83	Iliocostalis cervicis	Angles 3rd, 4th, 5th, 6th ribs.	Trans. processes 4th, 5th, 6th cervical vertebrae.	Extends cervical spine.
84	Iliocostalis dorsi	Upper borders angles of six lower ribs.	Angles upper 6 ribs; trans. process 7th cervical vert.	Extends thoracic spine.
85	Iliocostalis lumborum	Along with sacrospinalis.	Angles lower 6 or 7 ribs.	Extends lumbar spine.
86	Infraspinatus	Infraspinous fossa of scapula.	Greater tubercle of humerus.	Rotates humerus laterally.
87	Intercostales, ext. (11 pairs)	Lower border of rib above.	Superior border of rib below.	Draws ribs together; respiration; expulsion.
88	Intercostales, int. (11 pairs)	Lower border costal cartilage and rib above.	Superior border costal cartilage and rib below.	Draws ribs together; respiration; expulsion.
89	Interossei dorsales (foot)	Surfaces adjacent metatarsal bones.	Extensor tendons 4 lateral toes.	Abducts, flexes toes.
90	Interossei dorsales (hand)	Two heads from adjacent sides metacarpal bones.	Extensor tendons 2nd, 3rd, 4th fingers.	Abducts, flexes proximal phalanx.
91	Interossei plantares	Medial side 3rd, 4th, 5th metatarsals.	Extensor tendons 3rd, 4th, 5th toes.	Adducts, flexes toes.
92	Interossei volares	Sides of 2nd, 4th, 5th metacarpals.	Extensor tendons 2nd, 4th, 5th fingers.	Adducts, flexes proximal phalanx.
93	Interspinales	Under surface of spines of vertebrae near apex.	Posterior part of upper surface of spine below.	Supports spinal column.
94	Intertransversarii	Transverse process of vertebra.	Transverse process of vertebra.	Lateral flexion vertebral column.
95	Ischiocavernosus	Ramus of ischium.	Crus of penis.	Assists in erection of penis.
96	Latissimus dorsi	Spines of thoracic, lumbar vertebrae; lumbodorsal fascia; ilium crest; lower ribs; inf. angle of scapula.	Groove of intertubercular sulcus of humerus.	Adducts, extends humerus.
97	Levator ani	Pelvic surface ischial spine; int. obturator fascia.	Point of perineum; anococcygeal raphe; coccyx.	Draws anus upward, forward; supports viscera.
98	Levator palpebrae superioris	Upper border optic foramen.	Upper tarsal plate.	Raises upper lid.
99	Levator scapulae	Trans. processes 4 upper cervical vertebrae.	Medial angle of scapula.	Raises scapula.
100	Levator veli palatini	Apex petrous part temporal bone; eustachian tube.	Aponeurosis of soft palate.	Raises soft palate.
101	Levatores costarum (12 pairs)	Trans. processes 7th cervical, upper 11 thoracic vertebrae.	Medial to angle of corresponding rib below.	Aid in raising ribs in inspiration.
102	Lingualis inferior	Under surface of tongue at base.	Tip of tongue.	Shortens tongue.
103	Lingualis superior	Submucosa and septum of tongue.	Tip of tongue.	Shortens tongue; raises edges, tip.
104	Longissimus capitis	Trans. process upper thoracic, lower 4 cervical vertebrae.	Mastoid process of temporal bone.	Draws head backward; rotates head.
105	Longissimus cervicis	Trans. processes upper thoracic vertebrae.	Trans. processes 2nd to 6th cervical vertebrae.	Extends cervical vertebrae.
106	Longissimus dorsi	Trans., articular processes lumbar vertebrae; fascia.	Lower ribs; trans. processes thoracic vertebrae.	Extends thoracic vertebrae.
107	Longus capitis	Trans. processes 3rd to 6th cervical vertebrae.	Basal portion occipital bone.	Flexes head.
108	Longus colli	Bodies of 1st to 3rd thoracic vertebrae.	Trans. processes 5th to 6th cervical vertebrae.	Flexes cervical vertebrae.
109	Lumbricales (foot)	Tendons of flexor digitorum longus pedis.	Extensor tendons of 4 lateral toes.	Flexes proximal phalanges, extends distal phalanges.
110	Lumbricales (hand)	Tendons of flexor digitorum profundus.	Extensor tendon of each finger.	Raises mandible, closes jaws.
111	Masseter	Arch of zygoma.	Ramus and angle of mandible.	Puckers chin.
112	Mentalis	Incisive fossa of mandible.	Skin of chin.	Extends, rotates vertebral column.
113	Multifidus	Sacrum, sacroiliac ligament; mammillary processes of lumbar vertebrae; thoracic, cervical vertebrae.	Spines of vertebrae.	
114	Mylohyoideus	Mylohyoid line of mandible.	Hyoid.	Elevates hyoid; supports mouth floor.
115	Nasalis	Maxilla.	Skin over bridge of nose.	Muscle of facial expression.
116	Obliquus abdominis externus	Lower 8 ribs at costal cartilages.	Crest of ilium; linea alba through rectus sheath.	Flex and rotate vertebral column; compress abdominal viscera.
117	Obliquus abdominis internus	Inguinal ligament; iliac crest; lumbar aponeurosis.	Lower 3 or 4 costal cartilages; linea alba; conjoined tendon to pubis.	Flex and rotate vertebral column; compress abdominal viscera.

282. MUSCLES: MAN (Concluded)

Table represents an abridged listing of muscles. In no case is a complete atlas intended.

Ant. = anterior; ext. = external; inf. = inferior; int. = internal; lat. = lateral; med. = medial; post. = posterior; trans. = transverse; vert. = vertebra(e); cart. = cartilage.

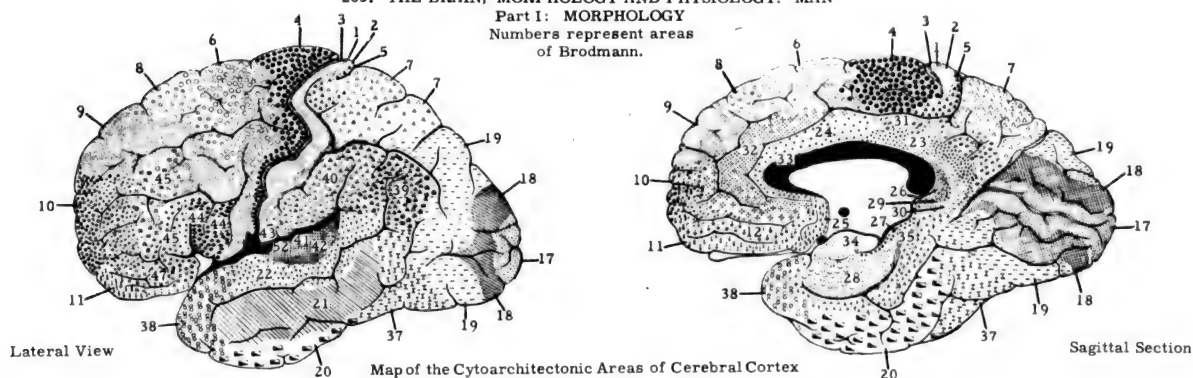
Muscle	Origin	Insertion	Action
118 Obliquus capitis inferior	Spine of axis.	Transverse process of atlas.	Rotates atlas and head.
119 Obliquus capitis superior	Transverse process of atlas.	Occipital bone.	Extension and lateral head movements.
120 Obliquus oculi inferior	Orbital plate of maxilla.	Sclera.	Rotates eyeball upward and outward.
121 Obliquus oculi superior	Lesser wing sphenoid above optic foramen.	Sclera.	Rotates eyeball outward and downward.
122 Obturator externus	Pubis, ischium, superficial surface obturator memb.	Trochanteric fossa of femur.	Rotates thigh laterally.
123 Obturator internus	Pubis, ilium, ischium, deep surface obturator memb.	Greater trochanter of femur.	Rotates thigh laterally.
124 Occipitalis	Posterior portion of Epicranium; occipital bone.	Galea aponeurotica.	Draws scalp backward.
125 Omohyoideus	Superior border of scapula.	Lateral border of hyoid bone via central tendon.	Depresses hyoid.
126 Opponens digiti quinti	Hamulus of hamate; transverse carpal ligament.	Medial aspect of 5th metacarpal.	Rotates, adducts 5th metacarpal.
127 Opponens pollicis	Ridge greater multangular; trans. carpal ligament.	First metacarpal volar.	Opposes thumb.
128 Orbicularis oculi	Medial aspect of orbit.	Skin about eyelids.	Closes lids.
129 Palmaris brevis	Palmar aponeurosis.	Skin of medial border of hand.	Tenses palm of hand.
130 Palmaris longus	Medial epicondyle of humerus.	Transverse carpal ligament; palmar aponeurosis.	Flexes wrist joint.
131 Pectineus	Iliopectineal line; pubis.	Femur distal to lesser trochanter.	Flexes; adducts thigh.
132 Pectoralis major	Clavicle, sternum, first 6 ribs, aponeurosis of obliquus abdominis externus.	Crest of intertubercular sulcus of humerus.	Adducts, flexes, medially rotates arm; depresses shoulder.
133 Pectoralis minor	Third to 5th ribs.	Coracoid process of scapula.	Draws shoulder forward and downward.
134 Peroneus brevis	Lateral surface of fibula.	Base of 5th metatarsal.	Abducts, plantar flexes foot.
135 Peroneus longus	Lateral condyle tibia; lateral surface fibula.	First cuneiform, 1st metatarsal.	Abducts, everts, plantar flexes foot.
136 Peroneus tertius	Medial surface of fibula.	Fifth metatarsal.	Everts, dorsiflexes foot.
137 Pharyngopalatinus	Soft palate.	Aponeurosis of pharynx.	Aids swallowing.
138 Piriformis	Ilium, 2nd to 4th sacral vertebrae.	Upper border of great trochanter.	Rotates thigh outward.
139 Plantaris	Lateral condyle of femur.	Posterior part of calcaneus.	Plantar flexes foot.
140 Platysma	Fascia of cervical region.	Mandible and skin around mouth.	Wrinkles neck skin; depresses jaw.
141 Popliteus	Lateral condyle of femur.	Back of tibia.	Flexes leg; rotates leg inward.
142 Procerus	Skin over nose.	Skin of forehead.	Draws down eyebrows.
143 Pronator quadratus	Volar surface of ulna.	Volar surface of radius.	Pronates hand.
144 Pronator teres	Medial epicondyle of humerus; coronoid of ulna.	Lateral surface of radius.	Pronates hand.
145 Psoas major	Lumbar vertebrae and fascia.	Lesser trochanter of femur.	Flexes trunk; flexes, medially rotates thigh.
146 Psoas minor	Last thoracic, first lumbar vertebrae.	Iliopectineal eminence of pubis.	Flexes trunk on pelvis.
147 Pterygoideus externus	Sphenoid; lateral pterygoid plate.	Mandible neck; temporomandibular joint capsule.	Protrudes mandible; opens jaws.
148 Pterygoideus internus	Lateral pterygoid plate; maxilla tuberosity.	Medial surface of mandible angle.	Closes jaws.
149 Pyramidalis	Front of pubis; anterior pubic ligament.	Linea alba.	Tenses abdominal wall.
150 Quadratus femoris	Ischial tuberosity.	Quadratus tubercle of femur.	Adducts, laterally rotates femur.
151 Quadratus labii inferioris	Mandible.	Skin about mouth.	Depresses lower lip.
152 Quadratus labii superioris	Maxilla.	Skin about mouth.	Raises upper lip.
153 Quadratus lumborum	Iliac crest; lumbodorsal fascia; lumbar vertebrae.	Last rib.	Laterally flexes lumbar vertebrae.
154 Quadratus plantae	Calcaneus and plantar fascia.	Tendons of flexor digitorum longus.	Aids in flexion of toes.
155 Quadriceps femoris	Rectus femoris and 3 vastus muscles.		Extends leg.
156 Rectus abdominis	Pubic crest.	Xiphoid; 5th to 7th costal cartilage.	Flexes lumbar vertebrae; supports abdomen.
157 Rectus capitis anterior	Lateral portion of atlas.	Occipital bone.	Flexes, supports head.
158 Rectus capitis lateralis	Upper surface transverse process of atlas.	Jugular process occipital bone.	Flexes, supports head.
159 Rectus capitis post. major	Spine of epistropheus.	Occipital bone.	Extends head.
160 Rectus capitis post. minor	Posterior tubercle of atlas.	Occipital bone.	Extends head.
161 Rectus femoris	Ant. inf. spine of ilium; dorsum ilii.	Patella; tubercle of tibia.	Extends leg; flexes thigh.
162 Rectus oculi inferior	Circumference of optic foramen.	Under side of sclera.	Adducts, rotates eye downward and inward.
163 Rectus oculi lateralis	Margin optic foramen, sphenoidal fissure.	Outer side of sclera.	Abducts eyeball.
164 Rectus oculi medialis	Circumference of optic foramen.	Inner side of sclera.	Adducts eyeball.
164 Rectus oculi superior	Upper border optic foramen.	Upper aspect of sclera.	Adducts, rotates eye upward and inward.
165 Rhomboideus major	Spines of 2nd to 5th thoracic vertebrae.	Vertebral margin of scapula.	Retracts, elevates scapula.
166 Rhomboideus minor	Spines 7th cervical to 1st thoracic vertebrae.	Vertebral margin of scapula.	Retracts, elevates scapula.
167 Risorius	Fascia over masseter.	Skin at angle of mouth.	Draws angle of mouth laterally.
168 Rotatores spinae (11 pairs)	Transverse process of thoracic vertebrae below.	Lamina of thoracic vertebrae above.	Extend, rotate vertebral column.
169 Sartorius	Anterior superior spine of ilium.	Tibia, upper medial.	Flexes thigh and leg.
170 Scalenus anterior	Transverse processes 3rd to 6th cervical vertebrae.	Tubercle of first rib.	Raises 1st rib.
171 Scalenus medius	Transverse processes 2nd to 6th cervical vertebrae.	First rib.	Raises 1st rib.
172 Scalenus posterior	Tubercles 4th to 6th cervical vertebrae.	Second rib.	Raises 1st and 2nd ribs.
173 Semimembranosus	Ischial tuberosity.	Medial condyle of tibia.	Flexes leg; extends thigh.
174 Semispinalis capitis	Trans. processes upper 6 thoracic, lower 4 cervical vertebrae.	Occipital bone.	Extends head.

175	Semispinalis cervicis	Trans. processes upper 6 thoracic, lower 4 cervical vertebrae.	Spines 2nd to 5th cervical vertebrae.	Extends, rotates vertebral column.
176	Semispinalis dorsi	Trans. processes 6th to 10th thoracic vertebrae.	Spines last 2 cervical, first 4 thoracic vertebrae.	Extends, rotates vertebral column.
177	Semitendinosus	Iscial tuberosity.	Medial aspect proximal portion of tibia.	Flexes leg; extends thigh.
178	Serratus anterior	Upper 8 or 9 ribs.	Vertebral border of scapula.	Draws scapula forward; rotates scapula to raise shoulder in abduction of arm.
179	Serratus posterior inferior	Spines 2 lower thoracic, upper 2-3 lumbar vertebrae.	Inferior border of 4 lower ribs.	Lowers ribs in expiration.
180	Serratus posterior superior	Ligamentum nuchae; spines upper thoracic vertebrae.	Second to 5th ribs.	Raises ribs in inspiration.
181	Soleus	Fibula; popliteal fascia; tibia.	Calcaneus by tendo calcaneus (Achilles).	Planter flexes ankle joint.
182	Sphincter ani externus	Tip of coccyx; surrounding fascia.	Tendinous center of perineum.	Closes anus.
183	Sphincter pupillae	Circular fibers of iris.		Contracts pupil.
184	Sphincter urethrae membranaceae	Ramus of pubis.	Median raphe of urethra.	Compresses urethra.
185	Spinalis capitis	Spines upper thoracic, lower cervical vertebrae.	Occipital bone.	Extends head.
186	Spinalis cervicis	Spines lower cervical, upper thoracic vertebrae.	Spines 2nd to 4th cervical vertebrae.	Extends vertebral column.
187	Spinalis dorsi	Spines of lower 2 thoracic, upper 2 lumbar vertebrae.	Spines upper thoracic vertebrae.	Extends vertebral column.
188	Splenius capitis	Ligamentum nuchae; last cervical, upper thoracic vertebrae.	Occipital bone.	Extends, rotates head.
189	Splenius cervicis	Spinous processes 3rd to 6th thoracic vertebrae.	Transverse processes 2-3 upper cervical vertebrae.	Extends, rotates head and neck.
190	Stapedius	Interior of pyramid of tympanum.	Posterior surface of neck of stapes.	Retracts stapes.
191	Sternocleidomastoideus	Two heads, sternum and clavicle.	Mastoid process.	Flexes, rotates head.
192	Sternohyoideus	Manubrium of sternum.	Lower border of body of hyoid.	Depresses hyoid and larynx.
193	Sternothyroideus	Manubrium of sternum.	Thyroid cartilage.	Depresses thyroid cartilage.
194	Styloglossus	Styloid process.	Side of tongue.	Raises and retracts tongue.
195	Stylohyoideus	Styloid process.	Hyoid.	Draws hyoid and tongue upward.
196	Stylopharyngeus	Styloid process.	Lateral wall of pharynx.	Raises and dilates pharynx.
197	Subanconeus	Posterior distal surface of humerus.	Posterior aspect of elbow joint.	Pulls capsule back in elbow joint extension.
198	Subclavius	1st costal cartilage and rib.	Clavicle.	Depresses lateral end of clavicle.
199	Subcostales	Inner surface of ribs.	Inner surface 1st, 2nd, 3rd rib below.	Raises ribs in inspiration.
200	Subscapularis	Subscapular fossa of scapula.	Lesser tubercle of humerus.	Rotates humerus medially.
201	Supinator	Lat. epicondyle of humerus; ulna, elbow joint fascia.	Radius.	Supinates hand.
202	Supraspinatus	Supraspinous fossa of scapula.	Greater tubercle of humerus.	Abducts humerus.
203	Temporalis	Temporal fossa and fascia.	Coronoid process of mandible.	Closes jaws.
204	Tensor fasciae latae	Iliac crest.	Iliotibial band of fascia lata.	Flexes, abducts thigh.
205	Tensor tympani	Cartilaginous portion of auditory tube.	Manubrium of malleus.	Tenses membrana tympani.
206	Tensor veli palatini	Scaphoid fossa of sphenoid; wall of auditory tube.	Aponeurosis of soft palate.	Tenses soft palate; opens auditory tube.
207	Teres major	Axillary margin of scapula.	Crest of intertubercular sulcus of humerus.	Adducts, extends, medially rotates arm.
208	Teres minor	Axillary margin of scapula.	Greater tubercle of humerus.	Laterally rotates arm.
209	Thyro-arytenoideus	Lamina of thyroid cartilage.	Muscular process of arytenoid cartilage.	Relaxes, shortens vocal cords.
210	Thyro-epiglotticus	Lamina of thyroid cartilage.	Epiglottis.	Closes inlet of larynx.
211	Thyrohyoideus	Thyroid cartilage.	Lower border greater cornu of hyoid.	Raises and changes form of larynx.
212	Tibialis anterior	Tibia and interosseous membrane.	First cuneiform and metatarsal, dorsal.	Dorsiflexes and inverts foot.
213	Tibialis posterior	Fibula; tibia; interosseous membrane.	Bases metatarsals and tarsals, except talus.	Plantar flexes and inverts foot.
214	Transversus abdominis	Costal cartilages lower 6 ribs; lumbodorsal fascia; iliac crest; inguinal ligament.	Lines alba through rectus sheath; conjoined tendon to pubis.	Compresses abdominal viscera.
215	Transversus linguae	Median raphe of tongue.	Dorsum and sides of tongue.	Alters shape of tongue.
216	Transversus perinei profundus	Inferior ramus of ischium.	Median raphe of perineum.	Draws back central point of perineum.
217	Transversus perinei superficialis	Tuberosity of ischium.	Central tendon of perineum.	Tensor of central point of perineum.
218	Transversus thoracis	Mediastinal surface of xiphoid and body of sternum.	Second to 6th costal cartilage.	Narrows the chest.
219	Trapezius	Occipital bone; ligamentum nuchae; spines of 7th cervical and all thoracic vertebrae.	Clavicle; acromion; spine of scapula.	Rotates scapula to raise shoulder in abduction of arm; draws scapula backward.
220	Triangularis	Lower border of mandible.	Angle of mouth.	Pulls mouth corners downward.
221	Triceps brachii	Infraglenoid tuberosity; shaft of humerus; (three heads).	Olecranon of ulna.	Extends forearm; adducts, extends arm.
222	Uvulae	Posterior nasal spine.	Uvula.	Raises uvula.
223	Vastus intermedius	Anterior, lateral aspects of femur.	Patella; common tendon of quadriceps femoris.	Extends leg.
224	Vastus lateralis	Capsule of hip joint; lateral aspect of femur.	Patella; common tendon of quadriceps femoris.	Extends leg.
225	Vastus medialis	Medial aspect of femur.	Patella; common tendon of quadriceps femoris.	Extends leg.
226	Verticalis linguae	Dorsal aspect of tongue.	Sides and base of tongue.	Alters shape of tongue.
227	Vocalis	Thyroid cartilage.	Vocal process of arytenoid cartilage.	Shortens vocal cords.
228	Zygomaticus	Zygomatic bone in front of temporal process.	Angle of mouth.	Draws mouth backward, upward.

283. THE BRAIN, MORPHOLOGY AND PHYSIOLOGY: MAN

Part I: MORPHOLOGY

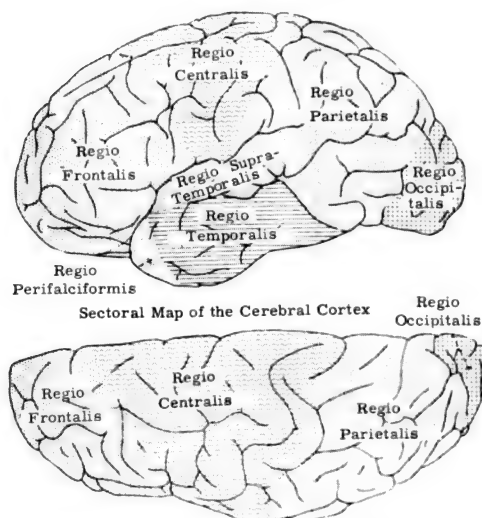
Numbers represent areas of Brodmann.



Lateral View

Map of the Cytoarchitectonic Areas of Cerebral Cortex

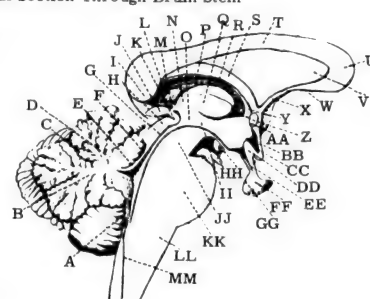
Sagittal Section



Sectoral Map of the Cerebral Cortex

Median Sagittal Section Through Brain Stem

- A=Epithelial roof and chorioid plexus of 4th ventricle
- B=Inferior vermis of cerebellum
- C=Fissura prima
- D=Sup. verm. of cerebellum
- E=4th ventricle
- F=Anterior medullary velum
- G=Cerebral aqueduct
- H=Lamina quadrigemina
- I=Splenium of corpus callosum
- J=Pineal body
- K=Posterior commissure
- L=Suprapineal recess
- M=Habenular commissure
- N=Habenula
- O=Hypothalamic sulcus
- P=Chorioid plexus of 3rd ventricle
- Q=Massa intermedia
- R=Epithelial roof of 3rd ventricle
- S=Body of fornix
- T=Corpus callosum
- U=Genu of corpus callosum
- V=Septum pellucidum
- W=Ros. of cor. callosum
- X=Lamina rostralis
- Y=Columna fornicis
- Z=Interventricular foramen
- AA=Anterior commissure
- BB=Lamina terminalis



- CC=Optic recess
- DD=Optic chiasma
- EE=Infundibulum
- FF=Hypophysis
- GG=Mammillary body
- HH=Oculomotor nerve
- II=Subthalamus
- JJ=Tegmentum of mesencephalon
- KK=Pons
- LL=Medulla
- MM=Central canal

Part II: VARIOUS BRAIN REGIONS AND THEIR FUNCTIONS

Region	General Functions	Sub-regions	Known Functions
Telencephalon			
1 Cerebral cortex	Highest level of integration; symbolism, memory, forecasting.	Prefrontal, frontal, parietal, occipital, temporal.	Association: autonomic; general motor, sensory; visual; auditory.
2 Rhinencephalon	Olfaction, "visceral brain," emotion.	Olfactory bulb, cortex; amygdala; hippocampus; fornix; mammillary bodies.	Association: autonomic-visceral integration; olfaction.
3 Corpus striatum	Smoothing of motor behavior; inhibition of posture, movement patterns; extrapyramidal relay.	Caudate nucleus, putamen, globus pallidus.	Forebrain association centers; motor relay (globus pallidus) for putamen.
Diencephalon			
4 Epithalamus		Habenular nucleus.	
5 Thalamus	Sensory relay to cortex; thalamocortical circuits.	Anterior, midline, medial, lateral, posterior, pulvinar, ventral.	Cortical relay nuclei: anterior, emotion(?); medial and ventral, sensory; pulvinar, gnostic and practic. Unspecific intralaminar nuclei. Basal ganglia relay ventromedian.
6 Metathalamus		Medial, lateral geniculate.	Medial: acoustic to supratemporal plane; lateral: visual to striate area.
7 Subthalamus		Subthalamic nucleus.	Hemiballismus.
8 Hypothalamus	Principal forebrain center for integration of visceral functions involving autonomic nervous system.	Anterior, middle, lateral, posterior.	Generally anterior part trophotropic (parasympathetic); posterior part ergotropic (orthosympathetic).
9 MESENCEPHALON	Postural reflexes; nuclei for cranial nerves.	Superior colliculus, inferior colliculus, substantia nigra, red nucleus, tegmentum, reticular formation (part of), basis peduncles, nucleus N III, IV, V (part of).	Relay for visual reflexes (protective), auditory reflexes, extrapyramidal junction of striatal and cortical influences; contributes to righting reflexes, tracts; facilitatory and inhibitory influences on motor performance.
Metencephalon			
10 Cerebellum	Maintenance of posture; equilibrium; coordination, smoothing of complex movements.	Corpus cerebelli, anterior posterior lobe; flocculonodular lobe.	"Vestibulocerebellum" (equilibration, maintenance of posture); postural reflexes, stabilizing, smoothing more complex movements initiated in cortex, facilitation of posture change.
11 Pons		Pontine nucleus, reticular formation, cerebellar peduncles, tracts, nucleus V (part of).	Relay between cerebro-cerebellar, motor inhibitory areas.
Myelencephalon			
12 Medulla oblongata	Reflex center for cardiac vasomotor, vomiting, deglutition, respiratory, gustatory, facial reflexes.	Nucleus V (part of), IX, XI, XII; inferior olivary, tracts; reticular nuclei of medullary tegmentum.	Posture.

/1/ Energy and water exchange; sexual function; sleep; vasomotor.

283. THE BRAIN, MORPHOLOGY AND PHYSIOLOGY: MAN (Continued)







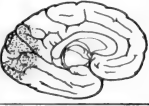
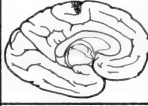
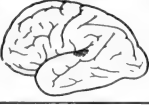

Part III: META- AND DORSAL THALAMUS

A = associational; D = diffuse associational; I = internal relay; E = external relay; U = unclassified or doubtful.

Nucleus	Function	Afferents	Efferents
1 Medialis dorsalis	A	Principal: some from medio ventral region (hypothalamus).	Frontal granular cortex.
2 Lateralis posterior	A	Principal: parietal cortex. Diffuse: sensorimotor, limbic, auditory, visual, frontal cortices. Nuclei, Lines 5-9 (q.v.).	Parietal field.
3 Lateralis anterior	A	Principal: parietal cortex. Diffuse: sensorimotor, auditory, visual cortices. Nuclei, Lines 5-9 (q.v.).	
4 Pulvinar	A	Principal: parietal association. Diffuse: frontal, sensorimotor, limbic, auditory, visual cortices. Subcortical: ventral posterior nucleus of thalamus. Nuclei, Lines 5-9 (q.v.).	Posterior parietal and temporal cortex, superior parietal lobule, posterior Sylvian region, supra-marginal gyrus, temporo-occipital region, area 18, superior colliculus and pretectum, posterior parietal, temporal and occipital (parasensory) fields.
5 Centrum medianum	D	Subcortical: reticular formation, other intralaminar thalamic nuclei.	Subcortical: caudate nucleus, corpus striatum.
6 Centralis medialis	D	Reticular formation. Intralaminar thalamic nuclei.	Cortical associational areas: frontal, cingulate, orbital. Caudate nucleus.
7 Centralis lateralis			
8 Ventralis anterior			
9 Reticularis anterior	D	Reticular formation; other intralaminar thalamic nuclei.	
10 Anterodorsalis	I	Corresponding opposite nucleus.	Retrosplenial region(?).
11 Anteromedialis	I	Mammillothalamic tract; limbic cortex. Nuclei, Lines 5-9, (q.v.).	Anterior gyrus cinguli.
12 Anteroventralis	I	Subcortical: nuclei, Lines 5-9, (q.v.); mammillothalamic tract. Cortical: gyrus cinguli.	Posterior gyrus cinguli.
13 Ventral anterior	I	Principal: globus pallidus. Diffuse from orbital, parietal, frontal, sensorimotor, limbic cortices. Nuclei, Lines 5-9 (q.v.).	Globus pallidus; prefrontal cortex.
14 Ventralis lateralis	I	Principal: superior cerebellar peduncle.	Precentral motor cortex; areas 4 and 6. Brachium conjunctivum.
15 Ventral medial	I		Globus pallidus; lateral frontal cortex.
16 Medial geniculate body	E	Inferior colliculi and parabigeminal body; auditory cortex.	Auditory cortex; parvicellular and magnocellular to temporal cortex in lower wall of Sylvian fissure.
17 Lateral geniculate body	E	Ganglion cell layer of retina.	
18 Ventral posterolateral	E	Medial lemniscus; spinothalamic tracts; sensorimotor cortex.	Sensorimotor cortex.
19 Ventral posteromedial	E	Trigeminal lemniscus; trigeminal thalamic tract.	Sensorimotor cortex.
20 Reticularis lateralis (posterior)	U	Unclassified or doubtful.	Cortex.
21 Midline ²	D/U	Spinothalamic tract; medial lemniscus.	Hypothalamus; basal ganglia; lateral thalamus nuclei.

/1/ Denotes nuclei not only adjacent to internal medullary lamina of thalamus but also others (such as midline nuclei, reticularis anterior and ventralis anterior), which when stimulated can evoke cortical and intrathalamic recruiting responses. /2/ Midline nuclei: rhomboideus, reuniens, paracentralis, parafascicularis, paraventricularis (anterior and posterior), parataenialis.

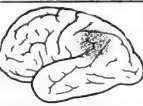



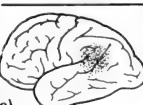
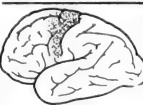


Part IV: VARIOUS CORTICAL CEREBRAL REGIONS AND THEIR FUNCTIONS

Function	Gross Region	Diagram	Area ¹	Principal Connected Pathways and Areas	Function	Gross Region	Diagram	Area ¹	Principal Connected Pathways and Areas
1 Vision	Occipital (striate cortex)		17(OC)	Optic radiation; lateral geniculate body of the thalamus; optic tract; chiasm; optic nerve; retina.	5 Equilibration	Temporal (first convolution)		22(TA) (?)	Probably similar to auditory mechanism.
					6 Olfaction	Temporal (Piriform area)		28(HB) 34(HA)	Lateral root; olfactory tract; olfactory bulb; fila olfactoria.
2 Visual elaboration	Occipital (parastriate) and Parietal (preoccipital)		18(OB) 19(OA)	Reticular formation of brain stem; areas PH, FC, LC ₂ and TE of Economo; areas 37, 8, 23, 21 of Brodman.	7 Somatic sensation	Parietal (post central convolution)		3(PA) 1(PB) 2(PC)	Connected through posteroventral nuclei with mesial and trigeminal fillets and spinothalamic tract; dorsal root; sensory root ganglion; peripheral sensory nerves.
3 Hearing (auditory-sensory)	Temporal (Heschl's gyrus)		41(TC)	Auditory radiation; medial geniculate body inferior colliculus; nucleus of lateral lemniscus; superior olive: dorsal and ventral cochlear nucleus in brain stem; cochlear nerve; spiral ganglion; hair cells in Organ of Corti.	8 Sensory elaboration (leg skills)	Parietal (superior parietal lobule)		5(PE _m) 7a(PE _p)	Association fibers with areas PC, FD _p , FEB _m , OA, FC, FD _Δ of Economo; areas 1, 44, 19, 8, 46 of Brodmann.
4 Hearing (auditory-psychic)	Temporal		42(TB) 22(TA)						

/1/ Areas of Brodmann are given numerically, followed in parentheses by associated areas of Economo. The latter have literal designations.

283. THE BRAIN, MORPHOLOGY AND PHYSIOLOGY: MAN (Continued)

Part IV: VARIOUS CORTICAL CEREBRAL REGIONS AND THEIR FUNCTIONS (Concluded)

Function	Gross Region	Diagram	Area ¹	Principal Connected Pathways and Areas	Function	Gross Region	Diagram	Area ¹	Principal Connected Pathways and Areas
9 Sensory elaboration (arm skills)	Parietal (inferior parietal lobule)		40(PF) 39(PG)	Association fibers with areas PC, TB and OA of Economo; areas 1, 42, 19 of Brodmann.	13 Elaboration of conscious thought	Frontal		9, 10, 11, 12, 13, 14(FD and variants) 24(LA)	Orbitofrontal cortex (areas 9, 10, 11, 12 of Brodmann) and posterior and medial orbital gyri (areas 13 and 14 of Walker) are connected to dorsomedial nuclei of thalamus which has hypothalamic connections. The anterior cingulate gyrus (area 24) is projection area of anterior nuclei of thalamus.
10 Speech (motor)	Frontal (3rd convolution, dominant hemisphere) Broca's area		44(FCB _m)	Receives afferents from PB of Economo, area 3 of Brodmann, sends impulses to areas FA and PE of Economo, areas 4 and 5 of Brodmann.					
11 Speech (sensory) (Gnosia)	Parietal (lower parietal lobule, dominant hemisphere)		40(PF) 39(PG)	Association fibers with areas PC, TB, OA of Economo; areas 1, 42, 19 of Brodmann.	14 Motion	Frontal (precentral area, motor and pre-motor)		4(FA) 6(FB)	Internal capsule, pyramidal decussation, corticospinal tracts, anterior horn cells, motor roots. Connected by way of latero-ventral nucleus and the superior cerebellar peduncle with the spinocerebellar afferents.
12 Memory	Temporal		Areas not definite						

/1/ Areas of Brodmann are given numerically, followed in parentheses by associated areas of Economo. The latter have literal designations.

Part V: BRAIN TRACTS

C = cervical; S = sacral; T = thoracic.

Tract	Origin	Termination	Pathway	Function
1 Acoustico-optic	Inferior colliculus.	Homolateral superior colliculus.	Diffuse.	Unknown.
2 Allen's fasciculus ¹	Solitary nucleus.	Ventral column: C3-T6.	Lateral funiculus along dorso-lateral edge of ventral column.	Associated with respiratory control.
3 Part of central tegmental fasciculus	Central gray of cerebral aqueduct.	About sac of inferior olive.	Flattened bundle running through tegmentum, oblique to horizontal plane, lateral to medial longitudinal fasciculus	
4 Arcuate fasciculus	Cerebral cortex of basal frontal lobes.	Cortex of temporal, lower parietal and occipital regions	Through base of angular gyrus into interior and middle frontal gyrus; in parietal and frontal opercula over upper border of insula.	Association bundle.
5 Bigeminopontine	Nucleus of parabigeminal body.	Pontine nuclei (lateral cells).	Lateral to medial lemniscus to middle strata of pons.	
6 Central acoustic	Contralateral and homolateral cochlear nucleus and olivary complex; nuclei of central acoustic tract.	Medial geniculate body.	With lateral lemniscus to ventrolateral surface of inferior colliculus; runs in brachium of inferior colliculus.	Auditory.
7 Cortico-habenular fibers	Hippocampus (and cingulate gyrus).	Medial habenular nucleus.	Via fornix and medullary stria of diencephalon.	
8 Corticospinal, lateral	Cerebral cortex.	Contralateral ventral column.	Internal capsule; cerebral peduncle; decussation of pyramids, lateral corticospinal tract.	Motor.
9 Corticospinal, ventral	Cerebral cortex.	Ipsilateral ventral column.	Internal capsule; peduncle, ventral corticospinal tract about anterior median fissure of cord.	Motor.
10 Cortico-tegmental fasciculus	Anterior central gyrus.	Diffuse tegmental nucleus.	Intermingled with corticospinal fibers, mostly in lateral 2/5 of cerebral peduncle.	
11 Cuneate fasciculus	Dorsal root ganglia C1-T6.	Cuneate nucleus.	Lateral portion of dorsal funiculus above T6.	Proprioception. Discriminative touch (upper extremities).
12 Dorsolateral fasciculus (Lissauer)	Dorsal root ganglia.	Substantia gelatinosa (Rolando), and nucleus proprius within 2-4 segments.	Dorsolateral to substantia gelatinosa of dorsal horn of gray matter.	Pain, temperature and light touch.
13 Fastigibulbar fasciculus	Fastigial nuclei.	Tegmental motor nuclei	Mingled with uncinate fasciculus of Russel in juxtarestiform body.	Cerebellar inhibitory path from anterior lobe to inhibitory region of bulbar reticular substance.
14 Fastigiospinal fasciculus	Fastigial nuclei.	Upper cervical segments of cord.	By way of spinal root of vestibular nerve.	Vestibular reflex connections to cervical musculature.
15 Fastigiovestibular fasciculus	Fastigial nucleus.	Contralateral superior, lateral, medial and spinal vestibular nuclei.	Through brachium conjunctivum in front of dentate nucleus, forming three limbs to distribute to vestibular nuclei.	
16 Frontal fasciculus, superior (Burdach's)	Basal frontal regions of cortex.	Temporal, lower parietal and occipital cortex.	Dorsal to insula.	Association fibers.
17 Frontopontine fasciculus	Posterior portions of superior and middle frontal gyri bordering on precentral gyrus.	Pontine nuclei.	Extreme medial and lateral portions of cerebral peduncle.	Cortical relay fibers to middle lobe of cerebellum.
18 Fasciculus gracilis (Goll)	Dorsal root ganglia T6-S5.	Nucleus gracilis.	Medial portion of dorsal funiculus.	Proprioception. Discriminative touch (lower extremities).
19 Habenulo-peduncular fasciculus ²	Habenular nuclei.	Interpeduncular nucleus.	Runs ventrolaterally; arches beneath centrum medianum through medial border of red nucleus and down along midventral line.	

/1/ Solitario spinal. /2/ Retroflex bundle of Meynert.

283. THE BRAIN, MORPHOLOGY AND PHYSIOLOGY: MAN (Continued)
Part V: BRAIN TRACTS (Continued)
C = cervical; S = sacral; T = thoracic.

	Tract	Origin	Termination	Pathway	Function
20	Habenulo-tegmental	Habenular nuclei.	Dorsal tegmental nucleus.		
21	Descending hypothalamic ³	Dorsomedial nuclei, posterior and lateral hypothalamic areas and perifornical areas.	Autonomic cells in medulla oblongata and intermediolateral cell column of cord.	Descends between mammillary body and red nucleus to ipsilateral reticular formation; dorsal to substantia nigra, then to region of vestibular fiber complex.	
22	Interfascicular fasciculus (Schultze)	Descending fibers of posterior funiculus.	Nucleus proprius of gray matter.	Between and mingled with fasciculus gracilis and cuneatus.	Reflex collaterals.
23	Interstitiospinal (of Cajal)	Mesencephalon, region of posterior commissure.	Intermediolateral cell column of cord (C8-T1).	Descends along ventromedian sulcus of cervical cord.	
24	Laterocerebellar	Lateral nucleus of medulla.	Cerebellum.	Runs with external arcuate fibers.	
25	Longitudinal fasciculus, dorsal (Schutz)	Hypothalamus and dorsal tegmental nucleus.	Somato-motor and autonomic motor nuclei of brain stem.	Continued into ventral fasciculus proprius of cord.	
26	Longitudinal fasciculus, inferior	Occipital cortex.	Temporal cortex.		Association fibers.
27	Longitudinal fasciculus, medial	Mesencephalon, at level of posterior commissural nuclei.	Through medulla, continued in cord as sulcomarginal fasciculus of Marie.	Bilateral, about midventral line between central gray matter and tectospinal fasciculus (in medulla).	Contains vestibular reflex fibers, fibers from reticular nuclei, abducens nucleus.
28	Mammillary fasciculus	Medial mammillary nuclei.	Anterior thalamic nuclei and tegmentum.	Runs dorsally from mammillary bodies, then bifurcates; one limb continues dorsally, the other caudally.	
29	Mammillotegmental fasciculus	Medial and lateral mammillary nuclei.	Tegmentum.	Initially a component of the principal mammillary fasciculus which it leaves to run caudally.	
30	Mammillothalamic fasciculus (Vicq d'Azyr)	Medial and lateral mammillary nuclei.	Anterior nuclear mass of thalamus.	Dorsostrally through medial thalamic wall.	
31	Olfactohabenular	Basal olfactory region, olfactory striatum, and medial part of amygdaloid complex.	Lateral habenular nucleus.	Lateral portion of medullary stria of diencephalon.	
32	Olfactopeduncular	Region about olfactory tubercle and putamen.	Region of substantia nigra.	Caudally beneath pallidum; ventral to internal capsule; medial border of peduncle.	
33	Olfactory	Olfactory bulb.	In three stria; medial, intermediate, and lateral olfactory stria.	Lies between gyrus rectus and medial orbital gyrus, covering olfactory sulcus.	Olfaction.
34	Olivo-cochlear bundle	Nuclei of olivary complex.	Organ of Corti.	Via auditory nerve.	Inhibition of neural response from Organ of Corti.
35	Olivospinal (Helweg)	Inferior olive.	Spinal gray, ventral column.	At junction of lateral and ventral funiculi.	
36	Optic	Ganglion cells of retina.	Lateral geniculate and/or superior colliculus.	Tract encircles thalamus ventrally.	Vision.
37	Perpendicular fasciculus	Inferior parietal lobule.	Fusiform gyrus.	Obliquely dorsomedially and ventrolaterally.	Association.
38	Probst's	Sensory cells associated with nucleus V in area of cerebral aqueduct or lateral reticular nucleus of the mesencephalon.	Intercalated nucleus and dorsal vagal nucleus.	Ventrolateral to solitary fasciculus and dorsomedial to the nucleus of the spinal tract of V.	Appears to link various parts of the trigeminal system; relates masticatory movements with salivation.
39	Reticulospinal fasciculus, lateral, direct	Reticular substance.	Gray matter of cord.	Lies in region of overlap of lateral corticospinal and rubrospinal tracts.	Extrapyramidal aspects of motor function.
40	Reticulospinal fasciculus, ventral, crossed	Reticular substance.	Gray matter of cord.	Ventrolateral to ventral corticospinal fibers.	Inhibitory pyramidal motor function.
41	Rubrospinal	Red nucleus.	Gray matter of cord.	Ventromedial to, and overlapping, lateral corticospinal tract.	Extrapyramidal function in man obscure.
42	Septomarginal fasciculus	Collaterals of dorsal funiculus fibers (fasciculus cuneatus).	Gray matter of cord.	Along posterior median sulcus in middle of posterior funiculus.	Proprioceptive reflex connections.
43	Solitary fasciculus	Fibers from cranial nerves VII, IX, and X.	Solitary nucleus.	Dorsomedial to spinal root of V; extends from level of medullary stria to caudal end of medulla.	Visceral afferent; oral end concerned with taste.
44	Spinal of trigeminal nerve	Cells of origin in semilunar ganglion.	Nucleus of spinal trigeminal tract.	Medial to restiform body; in position of Lissauer's zone and gelatinous substance of spinal cord.	Pain and temperature from face region.
45	Spinocerebellar fasciculus, ventral	Border cells about medial border of central lateral ventral column and cells about dorsal nucleus of Clark.	Vermis of anterior lobe of cerebellum.	On periphery of cord ventral to dorsal spinocerebellar, and lateral to lateral spinothalamic tract.	Exteroceptive.
46	Spinocerebellar fasciculus, dorsal (Flechsig)	Dorsal horn and dorsal nucleus of Clark.	Cortex of anterior cerebellar lobe, uvula and pyramis of vermis.	On periphery of lateral funiculus of cord.	Proprioceptive and exteroceptive.
47	Spinoolivary (Helweg)	Dorsal horn of spinal cord.	Inferior olive.	Ventral and superficial part of lateral funiculus between lateral and ventral spinothalamic tracts.	

/3/ Not yet demonstrated anatomically.

283. THE BRAIN, MORPHOLOGY AND PHSIOLOGY: MAN (Concluded)

Part V: BRAIN TRACTS (Concluded)

C = cervical; S = sacral; T = thoracic.

Tract	Origin	Termination	Pathway	Function
48 Spinothalamic, lateral	Dorsal horn of gray matter.	Tectum of midbrain.	Ventral and superficial part of lateral funiculus.	Pain and temperature from limbs and trunk.
	Proper nucleus of contra-lateral dorsal horn.	Posterolateral ventral nucleus of thalamus.	Lateral funiculus just medial to ventral spinocerebellar tract.	
49 Spinothalamic, ventral	Proper nucleus of contra-lateral dorsal horn.	Posterolateral ventral nucleus of thalamus.	Lateral portion of ventral funiculus.	Light touch.
50 Subcallosal fasciculus	Frontal cortex (Brodmann area 9).	Striate body.	Dorsal to caudate nucleus below radiation of corpus callosum.	
51 Tectospinal (Lowenthal)	Superior colliculus.	Spinal gray matter.	Ventromedial portion of ventral funiculus.	
52 Tegmental fasciculus central	Variable composition.		In reticular formation of medulla lateral to crossed vestibulospinal tract.	
53 Thalamic fasciculus	Fibers of brachium conjunctivum going to thalamus through tegmental field of Forel. Also fibers from globus pallidus.	Pallium. Thalamus.	Ventrally through Forel's field H1, between mammillothalamic tract and lenticular fasciculus.	
54 Vestibulofastigial	Vestibular nuclei and spinal nucleus of V.	Fastigial nucleus and vermian cortex.	Between restiform body and periventricular gray matter; in juxtarestiform body.	
55 Vestibulo-flocculonodular	Cells of origin in vestibular ganglion (Scarpa).	Cortex of flocculus and nodulus of cerebellum.		Vestibular.
56 Vestibuloglobose	Vestibular nuclei and spinal nucleus of V.	Globose nucleus and vermian cortex.	Between restiform body and periventricular gray matter in juxtarestiform body.	
57 Vestibulospinal, crossed, ventral	Medial, inferior and spinal vestibular nuclei.	Gray matter of cord.	Medial portion of ventral funiculus in sulcomarginal fasciculus of Marie.	Vestibular reflex.
58 Vestibulospinal, direct, lateral	Lateral vestibular nucleus.	Gray matter of cord.	Ventrolateral part of ventral funiculus and ventromedial portion of lateral funiculus.	Vestibular reflex.

284. ENCEPHALIC INDICES, EVOLUTIONARY SIGNIFICANCE: VERTEBRATES

Adapted from F. Tilney's "The Brain From Ape to Man," New York: Paul B. Hober, 1928.

Animal	Volume Index			Weight Index		
	Forebrain %	Midbrain %	Hindbrain %	Forebrain %	Midbrain %	Hindbrain %
Index: 82 and Above						
Hands, Fingers, Fingernails						
1 Man (Homo sapiens)	88	1	11	87	1	12
2 Gorilla (Gorilla gorilla)	84	2	14	84	2	14
3 Orangutan (Simia satyrus)	83	5	12	83	5	12
4 Monkey, Indian (Macaca rhesus)	83	2	15	84	2	14
5 Marmoset (Callithrix jacchus)	83	2	15	83	2	15
6 Gibbon (Hylobates hoolek)	82	2	16	82	2	16
Index: 70 to 80						
Paws, Hoofs, Claws						
7 Dog (Canis familiaris)	80	7	13	80	5	15
8 Cattle (Bos taurus)	80	2	18	80	2	18
9 Horse (Equus caballus)	80	2	18	80	2	18
10 Camel (Camelus bactrianus)	79	2	19	79	2	19
11 Cat (Felis catus)	77	6	17	75	4	21
12 Anteater, giant (Myrmecophaga sp)	75	6	19	73	5	22
13 Elephant (Elephas indicus)	72	2	26	71	2	27
14 Sloth, three-toed (Bradypus tridactylus)	70	10	20	70	10	20
Index: 20 to 60						
Wings, Fins, Paddles						
15 Ostrich (Rhea americana)	58	16	26	60	13	27
16 Turtle, soft-shelled (Aspionectes ferox)	57	15	28	53	20	27
17 Frog (Rana sylvatica)				21	37	42
18 Codfish (Gadus morrhua)	20	40	40	20	40	40
19 Dogfish (Squalus acanthias)				23	27	50

285. THE BRAIN, PLANIMETRIC COEFFICIENTS: PRIMATES

Planimetric coefficient = ratio of planimetric measurement of the structure adapted to that of the total axis hemisection at a fixed magnification.

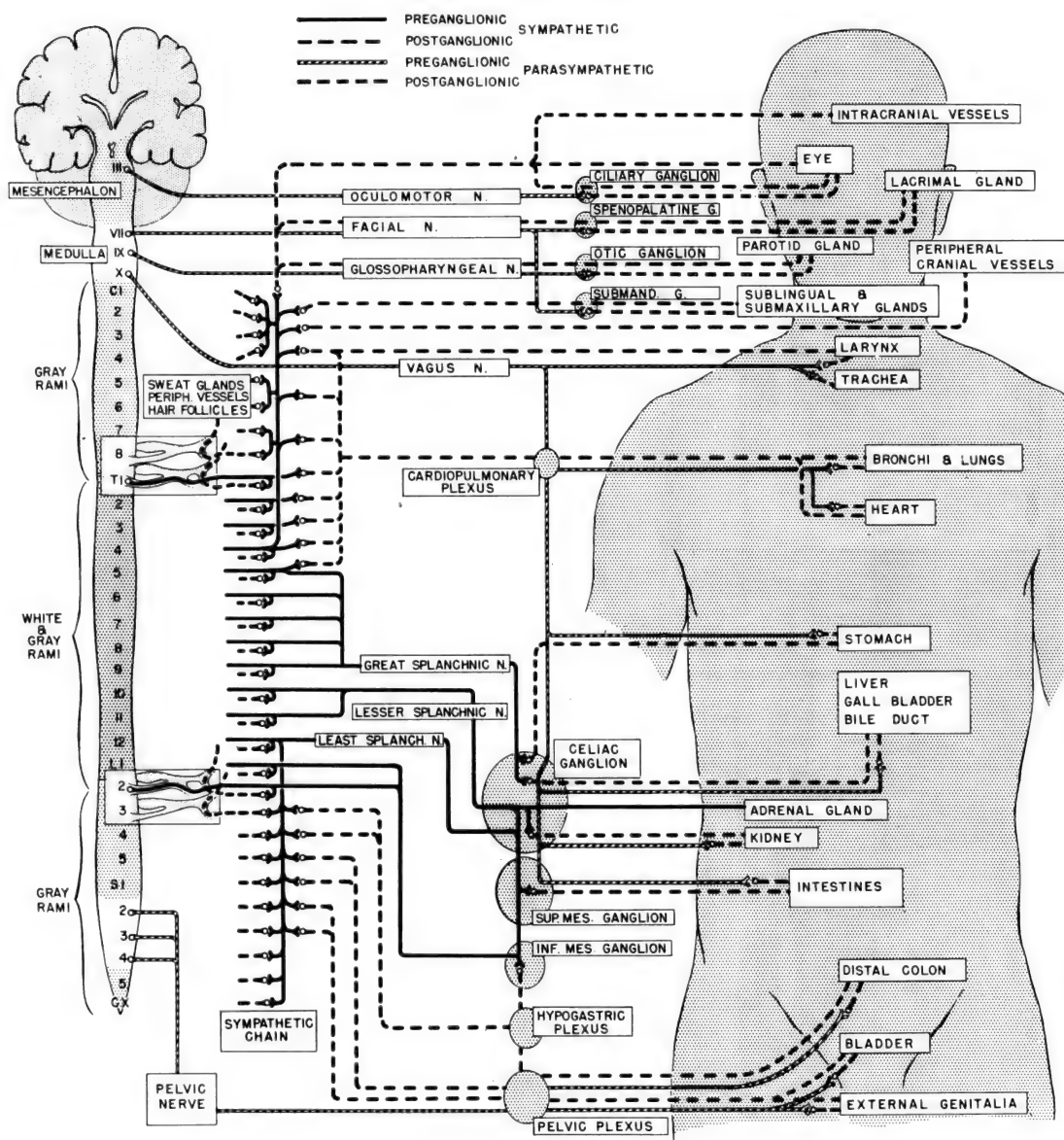
Adapted from F. Tilney's "The Brain From Ape to Man," New York: Paul B. Hober, 1928.

Structure	Man	Gorilla	Chimpanzee	Orang	Gibbon	Baboon	Macaque	Mycetes	Marmoset	Lemur	Tarsier
1 Pyramid	.183	.161	.172	.160	.138	.143	.147	.137	.064	.110	.032
2 Pontine nuclei	.550	.480	.400	.300	.200	.164	.150	.103	.095	.055	.057
3 Cerebral peduncle	.321	.187	.223	.110	.110	.190	.169	.144	.079	.086	.017
4 Inferior olive	.226	.186	.174	.172	.155	.125	.128	.120	.038	.060	.042
5 Nucleus dentatus	.176	.152	.136	.160	.134	.165	.155	.130	.077	.110	.059
6 Nucleus globosus	.023	.0095	.018	.015	.020	.023	.014	.032	.050	.032	.037
7 Red nucleus	.128	.096	.086	.087	.051	.060	.057	.081	.044	.012	.034
8 Superior cerebellar peduncle	.088	.047	.047	.064	.063	.044	.046	.036	.048	.033	.032
9 Inferior colliculus	.070	.111	.132	.131	.130	.155	.175	.182	.210	.223	.337
10 Superior colliculus	.104	.140	.125	.124	.132	.173	.158	.161	.154	.140	.230
11 Nucleus of Goll	.064	.086	.050	.048	.034	.086	.076	.131	.068	.041	.026
12 Nucleus of Burdach	.100	.081	.073	.093	.068	.065	.086	.113	.043	.049	.029
13 Nucleus of Dieters	.065	.072	.077	.054	.085	.060	.075	.114	.077	.082	.180
14 Nucleus of Schwalbe	.075	.070	.080	.055	.092	.095	.087	.090	.060	.045	.062

286. AUTONOMIC NERVOUS SYSTEM: MORPHOLOGY AND PHYSIOLOGY

S = sympathetic; P = parasympathetic; E = enteric.

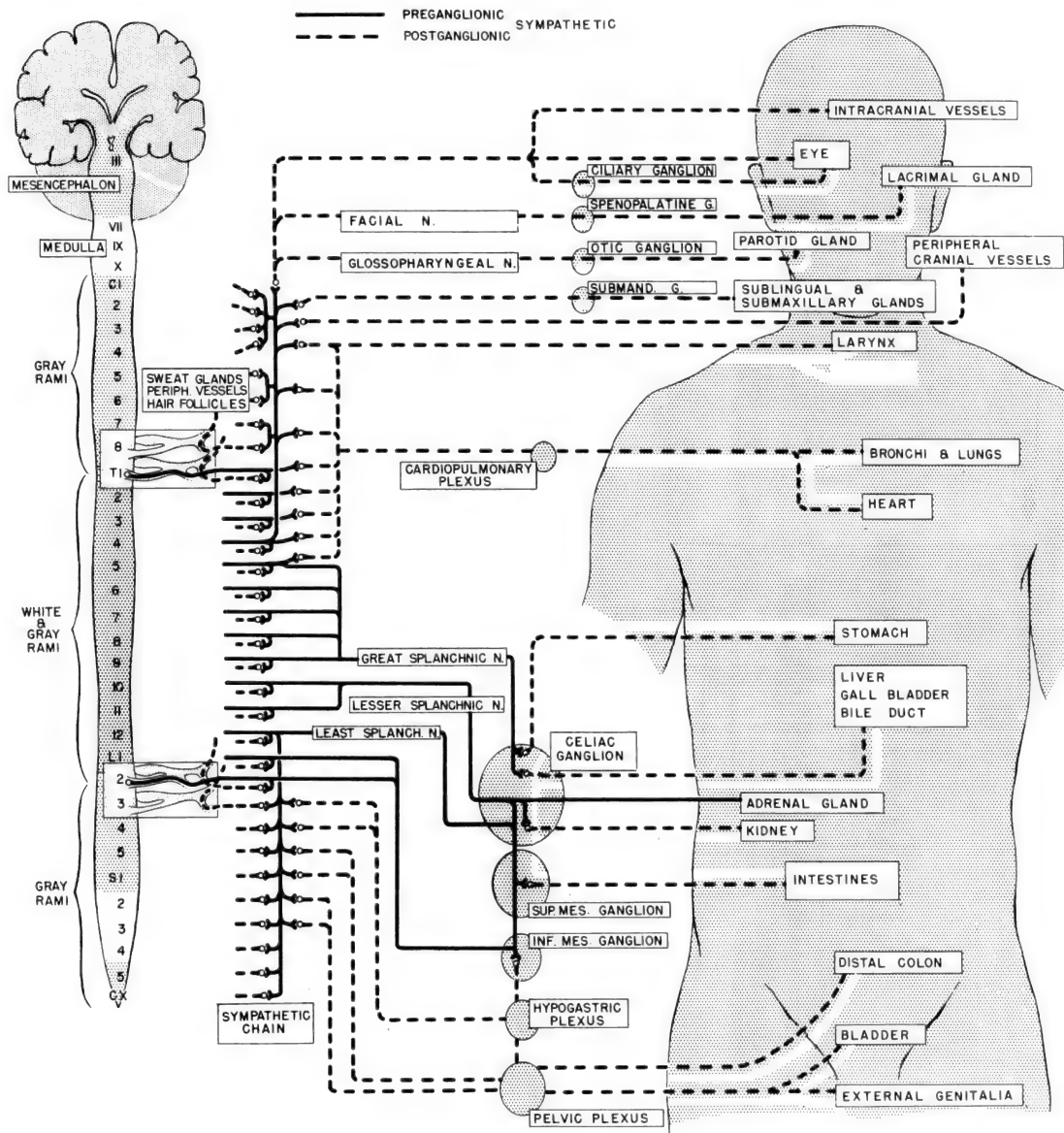
Part I: GENERAL



Division	Preganglionic Neurons	Outflow	Ganglia	Distribution	Effects of Increased Activity	
1	S	Intermediolateral column in spinal cord, C 8 to L 3.	Thoracic, lumbar nerves.	Sympathetic trunk.	Thoracic viscera, cardiovascular system, peripheral smooth muscle, sweat glands.	Inhibition of bronchial and gastrointestinal musculature; cardiac acceleration; increased vascular tonus, activation of peripheral smooth muscle and sweat glands.
				Abdominal and pelvic plexuses.	Abdominal, pelvic viscera and blood vessels.	Inhibition of visceral musculature; increased splanchnic vascular tonus.
2		Edinger-Westphal nucleus.	Cranial nerve III.	Ciliary.	Intraocular muscles.	Activation of ciliary muscle and circular muscle of iris.
3	P	Salivatory nuclei.	Cranial nerves VII, IX.	Sphenopalatine, otic, submandibular lingual.	Smooth muscle and glands.	Activation of salivary glands and glands in mucous membranes.
Vagus nucleus.		Cranial nerves X, XI.	Cardiac, pulmonary, enteric	Heart, some blood vessels, visceral musculature, glands.	Cardiac inhibition; activation of bronchial and gastrointestinal musculature and glands.	
Visceral nuclei in sacral segments of spinal cord.		S2, S3, S4.	Pelvic.	Pelvic viscera.	Activation of pelvic visceral musculature; control of bladder sphincter.	
6	E ¹	Vagus nuclei.	Vagus nerves.	Enteric.	E musculature, glands.	Activation of E musculature and glands.
7		Visceral nuclei in sacral segments of spinal cord.	S2, S3, S4.	Enteric.	Musculature and glands of colon and rectum.	Activation of musculature and glands of colon and rectum.

¹/ Actually a subdivision of P.

286. AUTONOMIC NERVOUS SYSTEM: MORPHOLOGY AND PHYSIOLOGY (Continued)
Part II: SYMPATHETIC CONNECTIONS



SC = sympathetic chain; WRC = white ramus communicans.

Organ	Species	Effector	Preganglionic Neurone		Postganglionic Neurone		Action
			Cell Body	Pathway	Cell Body	Pathway	
1	Eye	Dilator pupillae.	T1,2,3(Oc.C8&T4).	WRC, SC.	Superior cervical gan- glion.	Carotid plexus -- short and long ciliary nerve.	Dilatation.
2			C8, T1, 2.			Superior carotid nerve; ophthal- mic nerve; ciliary nerve.	
3			T1, 2, 3.			Carotid plexus; ophthalmic nerve.	
4		Muscle orbitalis.	T2, 3, 4, 5.			Superior carotid nerve; ophthal- mic nerve; ciliary nerve.	Vaso-con- striction. Retraction.
5		Bulbar, conjunc- tival vessels.	T1, 2, 3, 4.				
6		Nictitating mem- brane.					
7	Lacrimal gland	Blood vessels.	T1, 2, 3.	WRC, SC.	Superior cervical gan- glion.	Internal carotid plexus and branches.	Vaso-con- striction.

286. AUTONOMIC NERVOUS SYSTEM: MORPHOLOGY AND PHYSIOLOGY (Continued)

Part II: SYMPATHETIC CONNECTIONS (Continued)

SC = sympathetic chain; WRC = white ramus communicans.

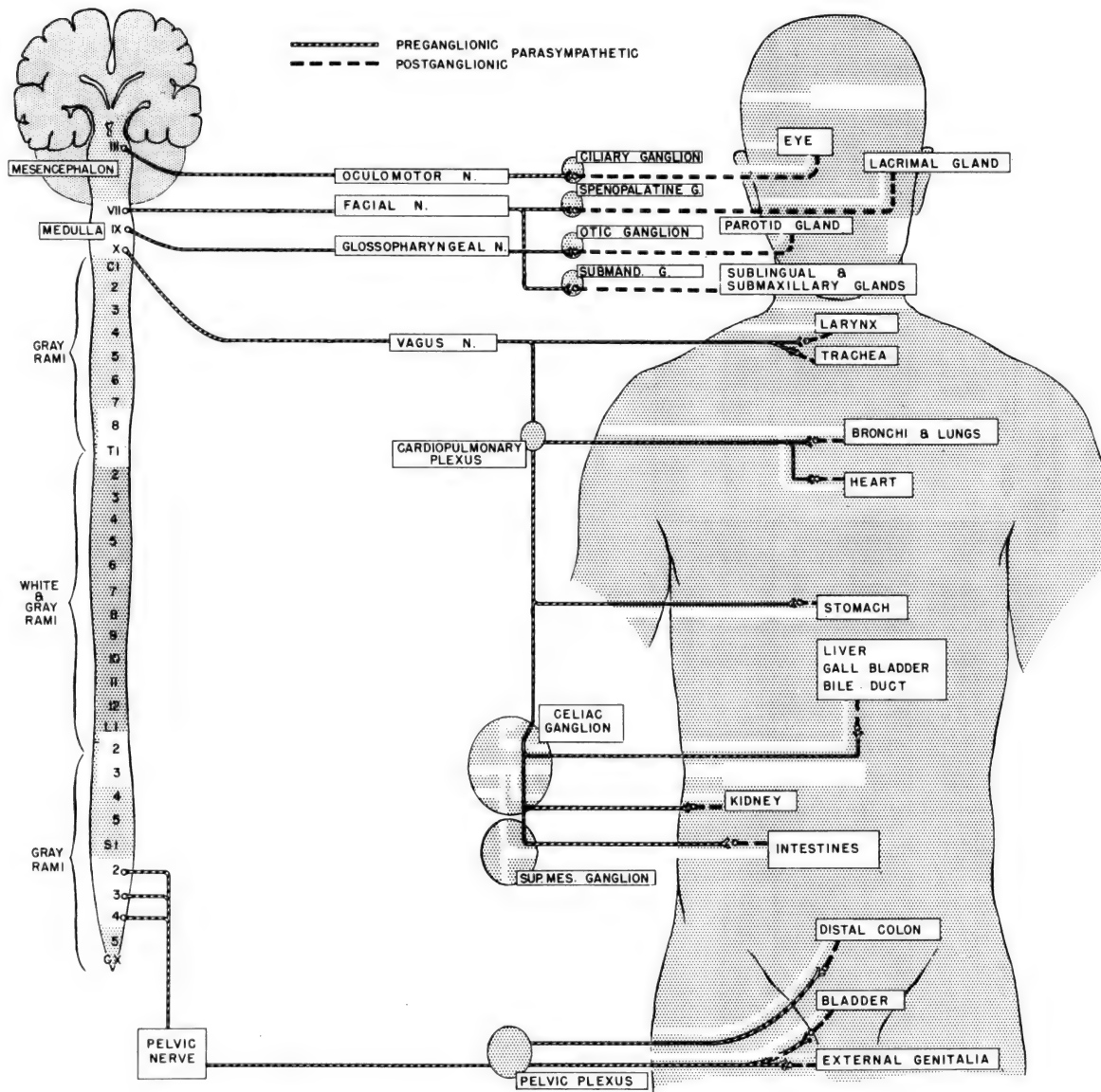
	Organ	Species	Effector	Preganglionic Neurone		Postganglionic Neurone		Action
				Cell Body	Pathway	Cell Body	Pathway	
8	Heart	Man	Mostly ventricular muscle, some auricular.	T1, 2, 3, 4, 5.	WRC, SC.	Superior cervical ganglion; middle cervical ganglion; inferior cervical ganglion; stellate ganglion; upper 2 or 3 thoracic ganglia.	Superior cervical cardiac nerve; middle cervical cardiac nerve; inferior cervical cardiac nerve; cardiac plexus.	Augmentation and acceleration.
9		Dog	Mostly ventricular muscle, some auricular.	T1-4.	WRC, SC.	Middle cervical ganglion.	Middle cardio-sympathetic nerve (accelerator nerve).	Augmentation and acceleration.
10		Cat	Mostly ventricular muscle, some auricular.	T1, 2-4, 5.		Stellate ganglion.	Cardio-accelerator nerve; coronary arteries; ventricles.	
11	Coronary artery	Man	Smooth muscle.	T1, 3, 4, 5.	WRC, SC.	Superior cervical ganglion; middle cervical ganglion; inferior cervical ganglion; stellate ganglion; and upper 2 or 3 thoracic ganglia.	Superior cervical cardiac nerve; middle cervical cardiac nerve; inferior cervical cardiac nerve; cardiac plexus.	Dilatation.
12	Blood vessels	Man	Meningeal arteries.	T1, 2.	WRC, SC.	Superior cervical ganglion.	External carotid plexus; middle meningeal artery.	Vasoconstriction.
13			Cerebral arteries.			Stellate ganglion.	Internal carotid plexus and branches.	
14			Vertebral system of brain.				Vertebral plexus.	
15	Blood vessels, sweat glands, and pilo-erection muscles	Man	Head, neck.	T1, 2, 3 (Oc. C8 & T4).	WRC, SC.	Superior cervical ganglion.	Gray rami to cervical plexus.	Vasoconstriction, sweating, pilo-erection.
16			Upper limb.	T1, 2-9, 10.		Superior cervical ganglion; middle cervical ganglion, inferior cervical ganglion; stellate ganglion.	Gray rami; brachial plexus and subclavian artery.	
17			Thoracic and upper abdominal wall.	T2-10.		Middle cervical ganglion; inferior cervical ganglion; stellate ganglion; upper thoracic ganglia.	Gray rami; intercostal nerves.	Sweating, pilo-erection.
18			Lower limb, trunk.	T6-L2.		Lumbar 1-4; sacral 1-3.	Gray rami; lumbar and sacral nerves.	
19	Adrenal medulla	Man	Cells of medulla.	T5-9, 10-L1, 2.	WRC, SC. (splanchnic).	Cells of adrenal medulla.	No postganglionic pathway.	Secretion.
20	Spleen	Dog	Smooth muscle of capsule, trabeculae and artery.	T5, 6-8, 9-12.	WRC, SC (splanchnic).	Thoracic ganglia 6-11, and celiac plexus.	Splenic nerve; celiac plexus; plexus on splenic artery.	Spleno-, vasoconstriction.
21			Splenic veins.	T5.		Stellate ganglion.	Gray rami; phrenic nerve; plexus on splenic artery.	Vasoconstriction(?).
22	Lung	Man	Trachea, bronchi	T2-4.	WRC, SC.	Inferior cervical, stellate, and upper 4 thoracic ganglia.	Cardiac accelerator -- deep cardiac and pulmonary plexus.	Tracheal, bronchial, dilatation.
23			Blood vessels.					Vasoconstriction.
24		Cat	Trachea, bronchi, blood vessels.	T3-7.				Tracheal, bronchial dilatations.
25	Submaxillary, sublingual glands	Man	Gland, vessels.	T1, 2, 3.	WRC, SC.	Superior cervical ganglion.	External carotid plexus and branches.	Vasoconstriction; weak secretion.
26	Parotid gland	Man	Gland, vessels.	T1, 2, 3.	WRC, SC.	Superior cervical ganglion.	External carotid plexus and branches.	Vasoconstriction; weak secretion(?).
27	Lower esophagus	Man	Smooth muscle.	T1-3, 4-6.	WRC, SC (great splanchnic).	Inferior or stellate, upper thoracic, celiac ganglia.	Esophageal rami, aortic plexus; left gastric, phrenic nerves.	Inhibits peristalsis.
28	Cardiac sphincter	Man	Smooth muscle.	T1-3, 4-6.	WRC, SC (great splanchnic).	Inferior or stellate, upper thoracic, celiac ganglia.	Esophageal rami, aortic plexus; left gastric, phrenic nerves.	Contraction.
29	Stomach	Man	Smooth muscle, gland.	T5, 6-10, 11.	WRC, SC (splanchnic).	Celiac ganglion.	Accompanies gastric artery.	Inhibits peristalsis.
30			Pyloric sphincter.					Contraction.
31			Blood vessels.					Vasoconstriction.
32	Pancreas	Man	Gland.	T5, 6-10, 11.	WRC, SC (splanchnic).	Celiac ganglion.	Accompanies pancreatic artery.	Secretion(?).
33			Blood vessels.					Vasoconstriction.
34	Liver	Man	Blood vessels.	T5, 6, 7-10.	WRC, SC (splanchnic).	Celiac ganglion.	Periarterial plexus of hypogastric artery.	Vasoconstriction.

Part II: SYMPATHETIC CONNECTIONS (Concluded)

SC = sympathetic chain; WRC = white ramus communicans.

Organ	Species	Effector	Preganglionic Neurone		Postganglionic Neurone		Action
			Cell Body	Pathway	Cell Body	Pathway	
35		Smooth muscle				Periarterial plexus of hepatic artery.	Relaxation.
36	Gallbladder	Sphincter of common bile duct.	T5, 6, 7-10.	WRC, SC (splanchnic).	Celiac ganglion.	Periarterial plexuses.	Contraction.
37	Small intestine, upper colon	Smooth muscle, glands.	T5, 6-10, 11.	WRC, SC (splanchnic).	Celiac and superior mesenteric ganglia.	Celiac and superior mesenteric rami.	Inhibitory.
38	Iliocecal sphincter	Blood vessels, sphincter muscle.	T5, 6-10, 11.	WRC, SC (splanchnic).	Celiac and superior mesenteric ganglia.	Celiac and superior mesenteric rami.	Vasoconstriction and contraction.
39	Lower colon, rectum	Smooth muscle.	T12, L1, 2, 3.	WRC, SC (lumbar splanchnic).	Inferior mesenteric ganglion.	Plexus of inferior mesenteric artery.	Contraction, inhibition.
40		Blood vessels.					Vasoconstriction.
41	Internal sphincter ani	Blood vessels, sphincter muscle.	L1, 2, 3.	WRC, SC (lumbar splanchnic).	Aortic ganglion.	Aortic and hypogastric plexus.	Vasoconstriction and contraction.
42	Kidney	Blood vessels, smooth muscle.	T5-L2.	WRC, SC (splanchnic).	Aortic or renal ganglion.	Renal plexus.	Vasomotor changes.
43	Ureter	Blood vessels, smooth muscle.	T5-12.	WRC, SC (splanchnic).	Aortic or renal ganglion.	Renal plexus and hypogastric nerve.	Rhythmic contraction.
44	Bladder	Detrusor vesicae.	L1-3.	WRC, SC (hypogastric nerve, pelvic plexus).	Vesical plexus, intramural ganglia.	Intramural plexus.	Relaxation.
45		Sphincter vesicae.			Vesical plexus.		Constriction for ejaculation.
46	Urethra	Compressor urethrae.	L1-3.	WRC, SC (hypogastric nerve, pelvic plexus).	Vesical plexus; intramural ganglia.	Prostatic plexus.	Contraction.
47	Prostate	Smooth muscle.	T12-L2	WRC, SC (hypogastric nerve, pelvic plexus).	Vesical plexus, prostatic plexus.	Prostatic plexus.	Contraction; ejaculation.
48	Seminal vesicles, vas deferens	Smooth muscle.	T12-L2	WRC, SC (hypogastric nerve; pelvic plexus).	Vesical plexus.	Plexuses of seminal vesicles and vas deferens.	Contraction; ejaculation.
49	Testes	Blood vessels.	T6-12.	WRC, SC.	Probably lower thoracic ganglia of sympathetic chain.	Splanchnic nerve, aortic and renal plexuses, spermatic plexus.	Vasoconstriction.
50	Corpora cavernosa	Blood vessels.	T12-L2.	WRC, SC.	Lumbar, sacral ganglia of sympathetic chain.	Hypogastric plexus, prostatic plexus, cavernous plexus.	Vasoconstriction.
51	Clitoris, labia minora	Blood vessels.	T12-L2.	WRC, SC.	Lumbar, sacral ganglia of sympathetic chain.	Hypogastric plexus, vaginal plexus, cavernous plexus.	Vasoconstriction.
52	Vagina	Smooth muscle.	T12-L2.	WRC, SC (hypogastric nerve).	Pelvic plexus, utero-vaginal plexus.	Vaginal plexus.	Contraction.
53	Uterus (non-pregnant)	Smooth muscle.	T12, L1, 2, 3-5.	WRC, SC (hypogastric nerve).	Pelvic plexus, utero-vaginal plexus.	Uterine plexus.	Relaxes.
54	Uterus (pregnant)	Smooth muscle.	T12, L1, 2, 3-5.	WRC, SC (hypogastric nerve).	Pelvic plexus, utero-vaginal plexus.	Uterine plexus.	Contracts.
55	Uterus (non-pregnant)	Smooth muscle.	T12, L1, 2, 3-5.	WRC, SC (hypogastric nerve).	Pelvic plexus, utero-vaginal plexus.	Uterine plexus.	Contracts.
56	Uterine tube (lower)	Smooth muscle.	T12, L1, 2, 3-5.	WRC, SC (hypogastric nerve).	Pelvic plexus, utero-vaginal plexus.	Uterine plexus.	Contracts.
57	Ovary, upper uterine tube	Vascular bed, stroma.	T6-12.	WRC, SC.	Probably lower thoracic ganglia of sympathetic chain.	Splanchnic nerve; aortic, renal plexuses; ovarian plexus.	Vasoconstriction, contraction.

286. AUTONOMIC NERVOUS SYSTEM: MORPHOLOGY AND PHYSIOLOGY (Continued)
Part III: PARASYMPATHETIC CONNECTIONS



Organ	Species	Effector	Preganglionic Neurone		Postganglionic Neurone	Action
			Cell Body	Pathway		
1 2 3 Eye	Man	Sphincter pupillae.	Visceral oculo-motor nucleus of Edinger-Westphal.	Oculomotor nerve; motor root; ciliary ganglion.	Ciliary ganglion -- short ciliary nerve.	Constriction of pupil.
		Ciliary muscle.			Ciliary ganglion -- short ciliary nerve (all fibers very large).	Accommodation.
		Sphincter pupillae, ciliary muscle (striated).			Ciliary ganglion -- short ciliary nerve (all fibers very large).	Constriction of pupil, accommodation (rapid).
4 Lacrimal gland	Man	Gland cells.	Nucleus salivatorius superior.	Nervus intermedius; great superficial petrosal nerve; vidian nerve.	Sphenal-palatine ganglion; zygomatic nerve; lacrimal nerve.	Secretion.
5 6 Heart	Man	Sino-atrial node; atrio-ventricular node, conduction system; auricular muscle.	Dorsal motor nucleus of vagus.	Superior, inferior, thoracic cardiac rami of vagus.	Intrinsic cardiac ganglia in wall of atrium and auricle.	Inhibitory; decreases heart rate.
	Dog			Right cardiovagal nerve; accelerator nerve; deep cardiac plexus. Left cardiovagal nerve; deep cardiac plexus.	Intrinsic ganglia on or above coronary sulcus in atrium.	

Part III: PARASYMPATHETIC CONNECTIONS (Concluded)

	Organ	Species	Effector	Preganglionic Neurone		Postganglionic Neurone	Action
				Cell Body	Pathway		
7	Coronary artery	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Superior, inferior, thoracic cardiac rami of vagus.	Intrinsic cardiac ganglia, adventitia, small branches of coronary artery.	Constriction.
8	Blood vessels	Man	Smooth muscle.	Demonstrated only for brain, meninges, face, and most glands.			Vaso-constriction.
9	Adrenal medulla	Man	None demonstrated.				
10	Spleen	Man	None demonstrated.				
11	Lung and trachea	Man	Smooth muscle of trachea, bronchial tree.	Dorsal motor nucleus of vagus.	Vagal branches; anterior, posterior pulmonary; deep cardiac plexuses.	Intramural tracheal, bronchial ganglia.	Tracheal, bronchial constriction
12			Tracheal, bronchial glands.				Secretion.
13	Submaxillary, sublingual glands	Man	Gland cells, blood vessels.	Nucleus salivatorius superior.	Nervus intermedius; 7th nerve; chorda-tympani; lingual nerve.	Submaxillary ganglion; submaxillary, sublingual branches.	Secretion, vasodilatation.
14	Parotid gland	Man	Gland cells, blood vessels.	Nucleus salivatorius inferior.	9th nerve; tympanic nerve; lesser superficial petrosal nerve; lingual nerve.	Otic ganglion; auriculo-temporal nerve.	Secretion, vasodilatation.
15	Lower esophagus	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; esophageal plexus.	Myenteric ganglionated plexus.	Increases tonus, peristalsis.
16			Cardiac sphincter.				Relaxation.
17	Stomach	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; gastric branches.	Myenteric ganglionated plexus.	Contraction; increases tonus, peristalsis secretion.
18			Gastric glands.			Submucosal ganglionated plexus.	
19	Pyloric sphincter	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; gastric branches.	Myenteric ganglionated plexus.	Diminishes tonus, inhibitory.
20	Pancreas	Man	Gland cells, blood vessels.	Dorsal motor nucleus of vagus.	Vagus nerve; pancreatic branches.	Pancreatic ganglia.	Secretion, vasodilatation.
21	Liver	Man	Hepatic cells.	Dorsal motor nucleus of vagus.	Vagus nerve; hepatic branches.	Intramural ganglia.	Secretion (?).
22	Gallbladder	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; hepatic, gastroduodenal plexus.	Intramural ganglia.	Emptying of gallbladder.
23	Biliary tree	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; hepatic, gastroduodenal plexus.	Intramural ganglia.	Elevates pressure of bile ducts.
24	Sphincter of common bile duct	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; hepatic, gastroduodenal plexus.	Intramural ganglia.	Relaxation.
25	Small intestine	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; celiac mesenteric branches.	Myenteric ganglionated plexus.	Contraction, peristalsis.
26			Gland.			Submucosal ganglionated plexus.	Secretion.
27	Ileocecal sphincter	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; celiac mesenteric branches.	Myenteric ganglionated plexus.	Inhibitory, diminishes tonus.
28	Upper colon	Man	Smooth muscle.	Dorsal motor nucleus of vagus.	Vagus nerve; celiac mesenteric branches.	Myenteric ganglionated plexus.	Contraction, peristalsis.
29			Glands.			Submucosal ganglionated plexus.	Secretion.
30	Lower colon	Man	Smooth muscle	S2, 3, 4.	Pelvic nerve; hypogastric nerve -- inferior mesenteric plexus.	Myenteric ganglionated plexus.	Contraction, vasodilatation, peristalsis, secretion.
31			Glands.			Submucosal ganglionated plexus.	
32			Internal sphincter ani.			Myenteric ganglionated plexus.	Inhibition; vasodilatation.
33	Kidney	Man	None demonstrated.				
34	Ureter	Man	None demonstrated.				
35	Bladder	Man	Detrusor vesicae.	S2, 3, 4.	Pelvic nerve (nervus eregentes).	Pelvic plexus; vesical, intramural ganglia.	Contraction.
36			Sphincter vesicae.				Relaxation.
37	Urethra	Man	Smooth muscle.	S2, 3, 4.	Pelvic nerve.	Pelvic plexus; vesical plexus; prostatic plexus.	Control of sphincter.
38	Prostate	Man	Smooth muscle.	S2, 3, 4.	Pelvic nerve.	Pelvic plexus; vesical plexus; prostatic plexus.	(?).
39	Seminal vesicles and vas deferens	Man	Smooth muscle.	S2, 3, 4.	Pelvic nerve.	Pelvic plexus; vesical plexus.	(?).
40	Testes	Man	None demonstrated.				
41	Corpora cavernosa	Man	Erectile tissue.	S2, 3, 4.	Pelvic nerve.	Pelvic plexus; cavernous plexus.	Vasodilatation; erection.
42	Clitoris and labia minora	Man	Erectile tissue.	S2, 3, 4.	Pelvic nerve.	Pelvic plexus; utero-vaginal plexus.	Vasodilatation; erection.
43	Vagina	Man	None demonstrated.				
44	Uterus	Cat	None demonstrated.				
45		Monkey	Smooth muscle.	S2, 3, 4.	Pelvic nerve.	Probably uterocervical ganglion.	Motility (?).
46	Cervix of uterus	Man	Smooth muscle.				
47	Uterine tube	Man	None demonstrated.				
48	Ovary	Man	None demonstrated.				
49	Thyroid gland	Man	No true secretory fibers present.				
50	Face	Man	Blood vessels.	Nucleus salivatorius superior(?)	Nervus intermedius, 7th nerve.	(?).	Vasodilation; blushing.

286. AUTONOMIC NERVOUS SYSTEM: MORPHOLOGY AND PHYSIOLOGY (Concluded)
Part IV: GANGLIA

Ganglia	Class.	Location	Preganglionic Connections	Postganglionic Distribution
1 Accessory	S	In relation to ventral nerve roots, communicating rami and S roots.	Ventral nerve roots.	Primary ventral rami of spinal nerves, visceral nerves.
2 Aortico-renal	S	Root of renal artery.	Splanchnic nerves.	Renal and aortic plexuses.
3 Bronchial	P	Bronchial plexuses.	Vagus nerves.	Bronchial musculature and glands.
4 Cardiac	P	Cardiac plexus.	Vagus nerves.	Heart, coronary vessels, pulmonary plexuses.
5 Celiac	S	Celiac plexus.	Splanchnic nerves.	Abdominal viscera and blood vessels.
6 Cervical sympathetic, inferior	S	Sympathetic trunk, level of vertebra T 1.	Thoracic nerves.	Brachial plexus, inferior cardiac nerve, common carotid plexus, vertebral nerve.
7 Intermediate	S	Sympathetic trunk, level of vertebra C 8.	Thoracic nerves.	Ansa subclavia, inferior cardiac nerve, sympathetic roots of nerves C 6, 7, 8.
8 Middle	S	Symp. trunk, level of vertebra C 6.	Thoracic nerves.	Middle cardiac nerve, S roots of nerves C 5, 6.
9 Superior	S	Sympathetic trunk, 2nd, 3rd, 4th cervical vertebrae.	Thoracic nerves.	Internal, external carotid nerves, sympathetic roots of nerves C 1-3, superior cervical cardiac nerves.
10 Cervical of uterus	P, S	Pelvic plexus adjacent to cervix of uterus.	Pelvic nerves, hypogastric plexus.	Uterus and vagina.
11 Ciliary	P	Orbit, between optic nerve and lateral rectus muscle.	Oculomotor.	Short ciliary nerves.
12 Enteric	E	Wall of enteric canal.	Vagus and sacral nerves.	Enteric muscles and glands.
13 Impar (or coccygeal)	S	Ventral surface of coccyx.	Lumbar spinal nerves.	Caudal spinal nerves.
14 Lingual	P	Posterior portion of tongue.	Facial and chorda tympani.	Lingual glands.
15 Mediastinal	S	Posterior mediastinum in relation to splanchnic nerves.	Splanchnic nerves.	Celiac plexus.
16 Mesenteric, inferior	S	Adjacent to inferior mesenteric artery.	Splanchnic nerves.	Inferior mesenteric and hypogastric plexuses.
17 Mesenteric, superior	S	Adjacent to root of superior mesenteric artery.	Splanchnic nerves.	Superior mesenteric, aortic, and renal plexus.
18 Myenteric	E	Between longitudinal and circular enteric muscle layers.	Vagus and pelvic nerves.	Enteric muscles.
19 Otic	P	Medial to mandibular nerve, just below foramen ovale.	Glossopharyngeal nerve.	Supplies auriculo-temporal nerve with fibers to parotid gland.
20 Pelvic	P, S	Adjacent to pelvic viscera.	Pelvic nerves, hypogastric plexus.	Pelvic viscera and blood vessels.
21 Pulmonary	P	Pulmonary plexuses.	Vagus nerves.	Bronchial plexuses.
22 Semilunar	S	Celiac plexus.	Splanchnic nerves.	Abdominal viscera and blood vessels.
23 Sphenopalatine ¹	P	Pterygopalatine fossa.	Facial nerve.	Pharyngeal, palatine, nasal, and orbital nerves.
24 Submaxillary	P	Between lingual nerve and duct of submaxillary gland.	Chorda tympani (through facial).	Submaxillary, sublingual, and lingual glands.
25 Submucous	E	Submucosa of enteric canal.	Vagus and pelvic nerves.	Enteric muscles and glands.
26 Sympathetic trunk	S	Ventrrolateral to vertebral column.	Spinal nerves T 1-L 3.	Sympathetic roots of spinal nerves, cephalic sympathetic, cardiac and splanchnic nerves.
27 Terminale	P	Adjacent to olfactory tract.	Nervus terminalis.	Anterior cerebral artery, vomero nasal organ, nasal mucosa.
28 Tracheal	P	Tracheal wall.	Vagus nerves.	Tracheal and bronchial plexus.

/1/ Supplied by greater superficial petrosal through facial nerve.

Part V: PLEXUSES

Plexus	Class.	Origin	Distribution
1 Adrenal	S	Celiac plexus.	Adrenal artery and gland.
2 Aortic	S	Sympathetic trunks.	Aorta and proximal portions of its branches.
3 Cardiac, superficial	P, S	Cervical and thoracic sympathetic cardiac nerves, branches of vagus nerves.	Heart, coronary vessels, anterior pulmonary plexuses.
4 Cardiac, deep	P, S	Right superior, middle and inferior cervical and thoracic sympathetic cardiac nerves, all cardiac branches of right vagus, left middle and inferior cervical and thoracic cardiac nerves, superior cervical and cardiac branches of left vagus.	Heart, coronary vessels, anterior pulmonary plexuses.
5 Carotid, common	S	Sympathetic trunk.	Common carotid artery.
6 Carotid, external	S	Superior cervical ganglion, common carotid plexus.	External carotid artery and its branches.
7 Carotid, internal	S	Superior cervical ganglion, common carotid plexus.	Internal carotid artery and its branches, caroticotympanic and deep petrosal nerves, cavernous plexus.
8 Cavernous	S	Internal carotid plexus.	Cavernous sinus, oculomotor, trochlear and ophthalmic nerves, ciliary ganglion, hypophysis.
9 Celiac	S	Intrinsic ganglia, splanchnic nerves.	Celiac artery and its branches.
10 Colic	S	Inferior mesenteric plexus.	Colon.
11 Duodenal	S	Superior mesenteric and pancreatic plexuses.	Duodenum and pancreas.
12 Enteric	E	Vagus, sacral nerves, intrinsic ganglia, esophageal, celiac, mesenteric and pelvic plexuses.	Enteric canal.
13 External maxillary	S	External carotid plexus.	External maxillary artery, submaxillary and otic ganglia.
14 Hepatic	P, S	Vagus nerves and celiac plexus.	Biliary system, hepatic blood vessels.
15 Hypogastric	S	Celiac, aortic, inferior mesenteric plexuses.	Pelvic plexuses.
16 Spermatic	S	Aortic and renal plexuses.	Spermatic artery, spermatic cord, testis.
17 Mesenteric, inferior	S	Celiac plexus, lumbar splanchnic nerves.	Inferior mesenteric artery and its branches.
18 Mesenteric, superior	S	Celiac plexus.	Superior mesenteric artery and its branches.
19 Meningeal, middle	S	External carotid plexus.	Middle meningeal artery.
20 Ovarian	S	Aortic and renal plexuses.	Ovarian artery, ovary.
21 Pancreatic	P, S	Vagus nerves, intrinsic ganglia, sympathetic trunks.	Pancreas, pancreatic ducts and vessels.
22 Pelvic	P, S	Hypogastric plexus, pelvic nerves, intrinsic ganglia.	Pelvic viscera and blood vessels.
23 Pulmonary	P, S	Vagus nerves, intrinsic ganglia, sympathetic trunks.	Bronchial plexuses, pulmonary vessels.
24 Phrenic	S	Celiac plexus, lesser and least splanchnic nerves.	Renal blood vessels; supplies adrenal gland, diaphragm, esophagus, inferior cava.
25 Prostatic	P, S	Pelvic plexus.	Prostate gland.
26 Renal	S	Celiac plexus, splanchnic nerves.	Renal blood vessels.
27 Sigmoid	S	Inferior mesenteric plexus.	Sigmoid colon.
28 Splenic	S	Celiac plexus.	Spleen, pancreas, stomach.
29 Tympanic	P, S	Internal carotid nerve, ramus from petrosal ganglion.	Tympanum, mastoid cells, auditory tube.
30 Uterine	P, S	Pelvic plexus.	Uterus.
31 Vaginal	P, S	Pelvic plexus.	Vagina.
32 Vesical	P, S	Pelvic plexus.	Urinary bladder.

287. NERVES: MAN

Cranial nerves are indicated by Roman numerals; spinal nerves by Arabic numerals and literal designation as follows: C = cervical; Th = thoracic; L = lumbar; S = sacral; Coc = coccygeal. Nerves listed are those considered most important; a complete atlas is not intended.

Nerve(s)		Distribution	Nerve(s)		Distribution
Cranial Nerves			Nerves of Shoulder Girdle and Upper Extremity (concluded)		
1	Olfactory (I)	Nasal mucous membrane.	78	Median (C6-Th1)	Intrinsic muscles of hand (abductor brevis, opponens and flexor brevis of thumb, medial two lumbricals), pronators quadratus and teres, long forearm flexors (of hand and fingers, except flexor profundus IV and V), skin of radial half of palm and fingers I-IV.
2	Optic (II)	Retina.	79	Ulnar (C8 and Th1)	Intrinsic muscles of hand (adductor pollicis, short muscles of little finger, all interossei, lateral two lumbricals), long forearm flexors (flexor carpi ulnaris, flexor profundus of fingers IV and V), skin of ulnar half of hand and of fingers IV and V.
3	Oculomotor (III)	Levator palpebrae, recti (medial, superior and inferior) and inferior oblique muscles of eye. Sphincter pupillae and ciliary muscles via ciliary ganglion and short ciliary nerves ¹ .	80	Radial (C5-Th1)	Extensor muscles of forearm, brachioradialis and extensor carpi, radialis longus.
4	Trochlear (IV)	Superior oblique muscle of eye.	81	Posterior interosseous	Supinator, extensor carpi radialis brevis, extensor muscles to hand and fingers, intrinsic extensor muscles of thumb.
5	Trigeminal (V)	Tentorium and dura of anterior cranial fossa.	82	Post. cutaneous of arm	Skin of back of arm.
	Ophthalmic division		83	Lower lat. cutaneous of arm	Skin of lateral side of arm.
6	Tentorial	Skin of upper eyelid, forehead, anterior scalp, mucosa of frontal sinus.	84	Post. cutaneous of forearm	Skin of back of forearm.
	Frontal		85	Dorsal digital	Skin of dorsal aspect of hand at base of thumb, index and middle fingers, and contiguous proximal surface of thumb, index and middle fingers.
7	Supratrochlear	Medial forehead, root of nose, medial commissure of eye.	86	Medial cutaneous of arm (C8, Th1)	Skin of medial side of arm.
8	Lacrimal	Lacrimal gland, conjunctiva, lateral commissure of eye.	87	Medial cutaneous of forearm (C8 and Th1)	Skin of medial side of forearm.
9	Nasociliary	Intraocular structures (sensory).	Nerves of Trunk, Thorax and Abdomen		
10	Long ciliary	Mucosa of posterior ethmoid cells and of sphenoid sinus.	88	Intercostobrachial (Th1-Th3)	Skin of axilla and medial side of arm.
11	Posterior ethmoidal	Mucosa of upper and anterior nasal septum, lateral wall of nasal cavity, skin of lower bridge and tip of nose.	89	Thoracic (Th2-Th12) (intercostal and post. rami)	Intercostal; skin of thorax and abdomen, intercostal muscles; post rami: skin of trunk, longitudinal back muscles.
12	Anterior ethmoidal	Mucosa of upper and anterior nasal septum, lateral wall of nasal cavity, skin of lower bridge and tip of nose.	90	Thoracic (Th7-Th12)	Oblique, transverse and rectus abdominal muscles.
13	Infratrochlear	Root and upper bridge of nose, conjunctiva, skin of eyelids, lacrimal sac.	91	Lumbar, sacral and coccygeal (posterior rami)	Skin of lower back from spinous process L1 through coccyx, deep muscles of lower back.
Maxillary division			Nerves of Abdomen, Pelvic Region, Perineum, Bladder and Genitals		
14	Middle meningeal	Dura of anterior cranial fossa.	92	Iliohypogastric (L1)	Skin above pubis and lateral gluteal region.
	Zygomatic		93	Ilioinguinal (L1)	Skin of pubis, inguinal region and upper 1/3 of penis.
15	Zygomaticofacial	Skin over zygomatic bone.	94	Genitofemoral (L1 and L2)	Creaster muscle, skin of upper scrotum and groin.
16	Zygomaticotemporal	Skin of anterior temple.	95	Superior gluteal (L4-S1)	Gluteus medius and minimus muscles.
17	Posterior superior alveolar	Upper molar teeth and gum, mucosa of maxillary sinus.	96	Inferior gluteal (L5-S2)	Gluteus maximus muscle.
18	Superior dental	Upper molar teeth.	97	Pudendal plexus (S2-S4)	Lower colon via hypogastric plexus.
19	Infraorbital	Skin of anterior cheek, side of nostril, skin and conjunctiva of lower eyelid.	98	Middle hemorrhoidal	Detrusor muscle and internal sphincter muscle of bladder via vesical plexus, rectum via pelvic plexus.
	Middle and ant. sup. alveolar		99	Pelvic (erigentes)	Levator ani and coccygeus muscles.
20	Sphenopalatine nerves via ganglion	Upper teeth (except molars), mucosa of maxillary sinus.	100	Muscular (S4)	External sphincter of anus, skin around anus.
21	Post. sup. lat. nasal	Mucosa of superior and middle nasal conchae.	101	Pudendal (S2-S4)	External sphincter of anus, transverse perineal and bulbocavernosus muscles, skin of lower scrotum (labia majorum), mucosa of urethra, bulb and corpus spongiosus of penis.
22	Post. sup. medial nasal	Mucosa of posterior part of nasal septum; post. ethmoid sinus.	102	Inferior hemorrhoidal	Skin of lower 2/3 of penis (clitoris), crus and corpus cavernosus of penis (clitoris).
23	Post. inferior nasal	Mucosa of middle and inferior nasal conchae.	103	Perineal	Skin over coccyx (anococcygeal nerves).
24	Palatines	Soft palate and tonsil via greater petrosal nerve and Vidian nerve.	Nerves of Lower Extremity		
Mandibular division			104	Lat. cutaneous of thigh (L2 and L3)	Skin of lateral side of thigh.
25	Spinous	Dura mater of middle cranial fossa.	105	Post. cutaneous of thigh (S1-S3)	Skin of back of thigh and lower buttock.
	Masticator		106	Femoral (L2-L4)	Muscles of front of thigh.
26	Masseter	Masseter muscle.	107	Ant. cutaneous of thigh	Skin of front of thigh and medial side of knee.
27	Deep temporal	Temporal muscle.	108	Saphenous	Skin of medial side of knee and ankle.
28	Pterygoid ext. and int.	Pterygoid muscles.	109	Obturator (L2-L4)	Adductor muscles of thigh, obturator externus skin of medial side of knee.
29	Buccinator	Skin of mid-cheek, mucosa of mouth.	Sciatic (L4-S3)		
30	Auriculotemporal	Skin of temple, superior part of ear, external acoustic meatus, tympanic membrane.	110	Nerve to hamstring muscles (L4-S3)	Muscles of back of thigh.
	Lingual				
31	Inferior alveolar	Mucosa of anterior 2/3 of tongue, lateral wall and floor of mouth.			
32	Mylohyoid	Mylohyoid muscle, anterior belly of digastric muscle.			
33	Dental, inferior	Lower teeth.			
34	Mental and inf. labial	Skin of chin, mucosa of lower lip.			
35	Abducens (VI)	Lateral rectus muscle of eye.			
36	Facial (VII)	Posterior auricular muscle, occipital belly of epicranium muscle, posterior belly of digastric muscle, stylohyoid, platysma and buccinator muscles, lip, chin and nose muscles, orbicularis oculi muscle, stapedius muscle.			
	Nervus intermedius ²				
	Greater superficial petrosal	Lacrimal gland via vidian nerve, sphenopalatine ganglion, anastomotic zygomaticotemporal nerve and lacrimal nerve ¹ , from soft palate and tonsil via posterior palatine nerve and sphenopalatine ganglion.			

37	Chorda tympani ³	Submaxillary and sublingual glands via lingual nerve and submaxillary ganglion ¹ , anterior 2/3 of tongue.	111	Tibial (L4-S3)	
38	Acoustic (VIII)		112	Posterior tibial	Muscles of back of calf, skin of heel.
39	Auditory (Cochlear)	Organ of Corti in cochlea.		Med. and lat. plantar	Skin of bottom of foot and toes, intrinsic muscles of foot.
	Vestibular	Macula of utricle in vestibule, cristae of ampullae in semi-circular canals.	113	Sural	Skin of back of calf and lateral side of foot.
	Glossopharyngeal (IX)			Common peroneal (L4-S2)	
40	Tympanic	Tympanic cavity, tympanic membrane, mastoid air cells.	114	Lat. cutaneous of calf	Skin of lateral side of knee and upper calf.
41	Pharyngeal	Mucosa of pharynx (from level of eustachian tube to the epiglottis).	115	Sural communicating	Skin of back of calf and lateral side of foot.
42	Stylopharyngeal	Stylopharyngeus muscle.	116	Superficial peroneal	Peroneus longus and brevis muscles of calf, skin of lower lateral side of calf and dorsum of foot.
43	Tonsillar	Fauces, including tonsil.	117	Deep peroneal	Anterior muscles of calf, extensor digitorum brevis, skin of dorsum of foot in region of toes I and II.
44	Lingual	Posterior 1/3 of tongue, posterior rim of soft palate, uvula.			Sympathetic Nervous System
45	Parotid	Parotid gland via nerve to digastric muscle, facial nerve, anastomotic nerve, otic ganglion and auriculo-temporal nerve ¹ .		Nerve or ganglion	
	Vagus (X)		118	Superior cervical	
46	Meningeal	Dura mater of floor of posterior cranial fossa.		Nerve to internal carotid artery	Vasoconstrictor fibers to circle of Willis and cerebral arteries, dilator pupillae and ciliary muscle ⁴ , lacrimal gland.
47	Auricular	External acoustic meatus, tympanic membrane, skin between ear and mastoid.	119	Nerve to external carotid artery	Blood vessels and sweat glands of face, submaxillary and sublingual glands ⁶ , parotid gland ⁷ .
48	Pharyngeal	Pharyngeal and palatine muscles, mucosa of pharynx.	120	Carotico-tympanic nerves	Tympanic plexus.
49	Superior laryngeal	Inferior pharyngeal constrictor and cricothyroid muscles, mucosa of larynx, epiglottis.	121	Laryngo-pharyngeal nerves	Pharyngeal and laryngeal plexus via superior laryngeal nerve.
50	Sup. and inf. cardiac ¹	Heart via cardiac plexuses.	122	Rami communicantes (C2-C4)	Cervical plexus, blood vessels and sweat glands of posterior scalp and neck.
51	Recurrent laryngeal	Intrinsic muscles of larynx (inferior laryngeal nerve) except cricothyroid, heart via cardiac plexus, trachea and esophagus via periaortic plexus.	123	Superior cardiac	Heart via cardiac plexuses.
52	Bronchial ¹	Bronchi via pulmonary plexuses.	124	Middle cervical	
53	Esophageal ¹	Esophageal muscle and mucosa via esophageal plexus.	125	Middle cardiac	Heart via cardiac plexuses.
54	Abdominal ¹			Rami communicantes	Upper brachial plexus.
	Anterior branch (right)	Anterior surface and lesser curvature of stomach and pylorus and duodenum via gastric plexuses, liver via celiac and hepatic plexuses.	126	Inferior cervical	
	Posterior branch (left)	Posterior surface of stomach (posterior gastric nerve), small intestine and ascending colon via superior mesenteric plexus, spleen and kidney via celiac, splenic and renal plexuses.	127	Inferior cardiac	Heart via cardiac plexuses.
56	Spinal accessory (XI)	Sternocleidomastoid and trapezius muscles.	128	Pulmonary nerves	Bronchi and pulmonary vessels via pulmonary plexuses.
57	Hypoglossal (XII)	Intrinsic and extrinsic tongue muscles.	129	Rami communicantes	Brachial plexus.
		Cervical Nerves		Vertebral ramus	Vasoconstrictor fibers to vertebral artery.
	Sensory			Thoracic, abdominal and pelvic	
58	Greater occipital (C2)	Scalp of medial half of back of head.	130	Rami communicantes (Ganglia 1-12)	Intercostal nerves.
59	Lesser occipital (C2 and C3)	Scalp of lateral half of back of head.	131	Thoracic cardiac nerves (Ganglia 1-4)	Heart via cardiac plexuses.
60	Great auricular (C2 and C3)	Most of ear, skin at angle of jaw.	132	Pulmonary nerves (Ganglia 1-4)	Bronchi and pulmonary vessels via pulmonary plexuses.
61	Anterior cutaneous of neck (C2 and C3)	Skin of front of neck.	133	Esophageal nerves (Th5-Th6)	Upper esophagus via esophageal plexus, lower esophagus and upper gastric orifice via periaortic plexus.
62	Supraclaviculars (C3 and C4)	Skin over shoulder girdle and upper 3 ribs.	134	Greater splanchnic (Ganglia 5-9), lesser splanchnic (Ganglia 10 and 11) and least splanchnic (Ganglion 12)	Celiac and aortico-renal ganglia. Via celiac plexus to following plexuses: (a) left gastric (esophagus and stomach), (b) hepatic (liver, gallbladder, stomach, duodenum and pancreas), and (c) splenic (spleen, pancreas, and stomach). Also via following plexuses with branches from periaortic plexus: adrenal (adrenal gland), renal (kidney) and superior mesenteric (small intestine, cecum, appendix, ascending and transverse colon).
63	Motor				
	Roots C1-C3	Infraspinatus muscles (via ansa hypoglossi), occipito-vertebral muscles.			
64	Roots C2 and C3	Sternocleidomastoid muscle.			
65	Roots C3 and C4	Levator scapulae and trapezius muscles.			
66	Roots C3-C7	Longus colli and scalenus muscles.			
67	Phrenic (C3-C5)	Diaphragm.			
		Nerves of Shoulder Girdle and Upper Extremity			
68	Long thoracic (C5-C7)	Serratus anterior muscle.	135	Splanchnics plus fibers from lumbar ganglia	Aortic plexus to spermatic (or ovarian) plexus (gonads) and inferior mesenteric plexus (descending colon and rectum).
69	Anterior thoracic (C5-Th1)	Pectoralis major and minor muscles.			
70	Dorsal scapular (C5)	Levator scapulae and rhomboid major and minor muscles.	136	Rami communicantes	Lumbosacral plexus, blood vessels and sweat glands of lower extremities.
71	Subclavian (C5 and C6)	Subclavius muscle.			
72	Suprascapular (C5 and C6)	Supraspinatus and infraspinatus muscles.	137	Hypogastric nerves (continuation of aortic plexus)	Inferior hypogastric, hemorrhoidal (rectum), vesical (bladder), prostatic and uterovaginal plexuses.
73	Thoracodorsal (C6-C8)	Latissimus dorsi muscle.			
74	Subscapulars (C5 and C6)	Subscapular and teres major muscles.			
75	Axillary (C5 and C6)	Deltoid and teres minor muscles, skin over shoulder.			
76	Musculocutaneous (C5-C7)	Biceps coracobrachialis, brachialis muscles.			
77	Lateral cutaneous of forearm.	Skin of radial side of forearm.			

/1/ Parasympathetic. /2/ Part of VIII cranial nerve. /3/ Branch of facial nerve but carries fibers to and from nervus intermedius. /4/ Via ciliary ganglion and short ciliary nerves. /5/ Via deep petrosal nerve, vidian nerve and sphenopalatine ganglion. /6/ Via submaxillary ganglion. /7/ Via external carotid artery.

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1/ Velocity (v) in m/sec (myelinated fibers) in vertebrates is directly proportional to outside diameter in μ ; $v = kd$. $k \approx 6$ in mammals; $k \approx 2$ in frogs. Temperature coefficient of velocity is 1.8 for 10° .
 2/ A fibers = myelinated fibers of somatic system, subdivided into α , β , γ and δ ; B fibers = myelinated (usually preganglionic) fibers of autonomic nervous system; C = non-myelinated fibers. 3/ Presumed to be Mauthner's fibers. 4/ Presumably nerve net.

Species		Nerve, Fiber Type	Conduction Velocity m/sec ¹	Fiber Diameter μ	Temperature °C	Species	Nerve, Fiber Type	Conduction Velocity m/sec ¹	Fiber Diameter μ	Temperature °C
Vertebrata						Vertebrata (concluded)				
1	Mammalia	Large motor fibers	(30-65)	(1-30)		52	Amphibia (concluded)			
2		Ulnar and median	(49-69)		In vivo	53	Frog (<i>Rana catesbeiana</i>)	Small motor fibers	15	8
3		(to hand)	(66-69)		In vivo	54	(concluded)		10	5
4	Man	Ulnar and median	(47-58)		In vivo	55	Pisces		7	4
5		(to forearm)	120			56	Bullhead (<i>Ameiurus</i> sp)	Spinal pathway ³	50-60	22-43
6		Tibia & peroneus (to foot)	(47-58)			57	Catfish	Optic n. (proximal)	3-8	10-15
7		Sciatic	65		18.7	58		(peripheral)	15-25	
8		Large motor fibers	110	20		59	Pike (<i>Esox</i>)	Olfactory n.	16-24	20
9			80	15		60	Ray (<i>Raja squaleus</i>)	Dorsal roots	8-36	
10			50	10		61	Torpedo (<i>Torpedo</i> sp)	Electric organ (aff.)	20-30	18-19
11		N. to gastrocnemius		(11-16)		Invertebrata				
12		N. to soleus		(9-12)		62	Crustacea			
13		N. to tibia ant.		(9-15)		63	Crab (<i>Carcinus maenas</i>)	Leg	4.4 (3.9-5.5)	30
14		Saphenous, α fibers ²	60			64	Crayfish (<i>Cambarus</i> sp)	Lateral giant fibers	(10-15)	(75-150)
15		Small motor fibers	40	8		65		Median giant fibers	(15-20)	(100-250)
16			30	6		66	Lobster (<i>Homarus</i> spp)	Leg nerve fibers	(42-10)	(35-70)
17			20	4		67	Mud shrimp (<i>Callinassa</i> sp)	Giant fibers	(6.0-7.5)	(35-40)
18			10	2		68	Prawn (<i>Leander</i> sp)	Giant fibers	(18-23)	20-22
19	Cat	N. to gastrocnemius		(3-8)		69	Insecta			17
20		N. to soleus		(3-6)		70	Cockroach (<i>Periplaneta</i> sp)	Giant fibers	(9-12)	(10-40)
21		N. to tibia ant.		(3-6)		71	Xiphosura			
22		Splanchnic, β fibers ²	(70-81)	(13-15)	35	72	King crab (<i>Limulus</i> sp)	Ambulacral n.	(1.3-4.6)	
23		Afferent fibers				73		Heart plexus	1.5	
24		Flexor hamstrings	(47-111)	(13-22)	37.5	74	Mollusca			
25		Pre-tibial	(27-99)	(13-22)	37.5	75	Cuttlefish (<i>Sepia</i> sp)	Giant fibers	(6-13)	200
26		Gastrocnemius	(30-104)	(13-22)	37.5	76		Stellar n.	(2.2-8.1)	(30-180)
27		Spinal cord				77	Octopus (<i>Octopus</i> sp)	Mantle	2	
28		Pyramidal tract	(1.8-164)	(1-12.5)	37	78	Slug (<i>Ariolimax columbianus</i>)	Pedal n.	0.83	1-35
29		Dorsal columns	(22-66)			79			0.50	1-35
30		Dorsal spinocerebellar	85-160	(16-18)		80			0.05-0.48	10-15
31		A fibers (fastest) ²	100			81	Snail (<i>Helix pomatia</i>)	Intestinal n.	(4.7-22.3)	(40-718)
32		B fibers ²	4.5	3		82		Stellar n.	18	260
33		C fibers ²	0.6	1-5		83		Giant fibers	23.5 (21.5-25)	350
34	Dog	Sciatic	(59-102)		38	84		Giant fibers	30 (27.5-32)	450
35		Chorda tympani	36.4	8.2	38	85	Annelida		35	520
36		Splanchnic	55.0			86	Clamworm (<i>Neanthes virens</i>)	Lateral giant fibers	5 (4-6)	(30-37)
37		Saphenous	(72-83)	(14.4-17)	38	87		Median giant fiber	4.5	(15-18)
38	Rabbit (<i>Oryctolagus cuniculus</i>)	Depressor	5	(2-4)	38	88		Medial giant fibers	2.5	(7-9)
39		Peroneal	69	20.4	37.5	89	Earthworm (<i>Lumbricus</i>	Lateral giant fibers	11.3 (7.5-15)	(40-60)
40	Rat (<i>Rattus rattus</i>)	Tibial	37.8	(2.6-12.5)	20	90	terrestris	Median giant fiber	30 (15-45)	(50-90)
41	Reptilia					91	Leech (<i>Hirudo</i> sp)	Ganglionic cords	(0.02-0.03)	
42	Blow snake (<i>Pituophis catenifer</i>)	Spinal motor pathways	(11.0-36.9)		14-24	92	Lugworm (<i>Arenicola</i> sp)	Giant fiber	2	25
43	Bull snake (<i>Pituophis</i> sp)	Hypoglossal	(7.5-11.2)		22-27	93	Sabellid (<i>Myxicola</i> sp)	Giant fiber	(6-20)	(100-1000)
44	Garter snake (<i>Thamnophis</i> sp)	Spinal motor pathways	(3.42-35.1)		10.5-22	94	Sandworm (<i>Lumbrineris hebes</i>)	Median dorsal fiber	10	130
45	King snake (<i>Lampropeleis</i> sp)	Hypoglossal	10			95		Median ventral fiber	4.5	27
46	Amphibia					96		Nerve cord	0.5	
47	Frog (<i>Rana</i> sp)	Sciatic, A fibers ²	2 x d ¹ , 40 max	(3-20)	24 ¹	97	Coelenterata			
48		Muscle nerve	(10-40)	15	22	98	Aurelia (<i>Aurelia</i> sp)	Nerve net	0.229	
49			(4-8)	5	22	99	Portug. man-of-war (<i>Physalia</i> sp)	Filaments ⁴	0.121	
50		Large motor fibers		(7-11)		100	Sea anemone (<i>Calliactis</i>	Column n. net, longit.	0.1	26
51		Small motor fibers		(4-6)		101	parastica)	circular	0.15	
52	Frog (<i>R. catesbeiana</i>)	C fibers ²	(0.2-0.6)	<1		102		radial	0.04	
53		Large motor fibers	30	15		103		Mesentery n. net, longit.	1.2	
54			25	12						
55			20	10						

289. DELAYS AT SYNAPSES AND PERIPHERAL JUNCTIONS

Synaptic delay is the time between first electrical sign of impulse in presynaptic terminals and first electrical sign of response in the postsynaptic unit. The latter is often a synaptic potential and not a spike. Values are not strictly comparable because of varying interpretations with regard to the exact moment an impulse enters presynaptic terminals or with respect to bases for correction for conduction. Because spike may be initiated any time up to or slightly beyond crest of junction potential, values for crest time (foot to summit) of such potentials are listed separately.

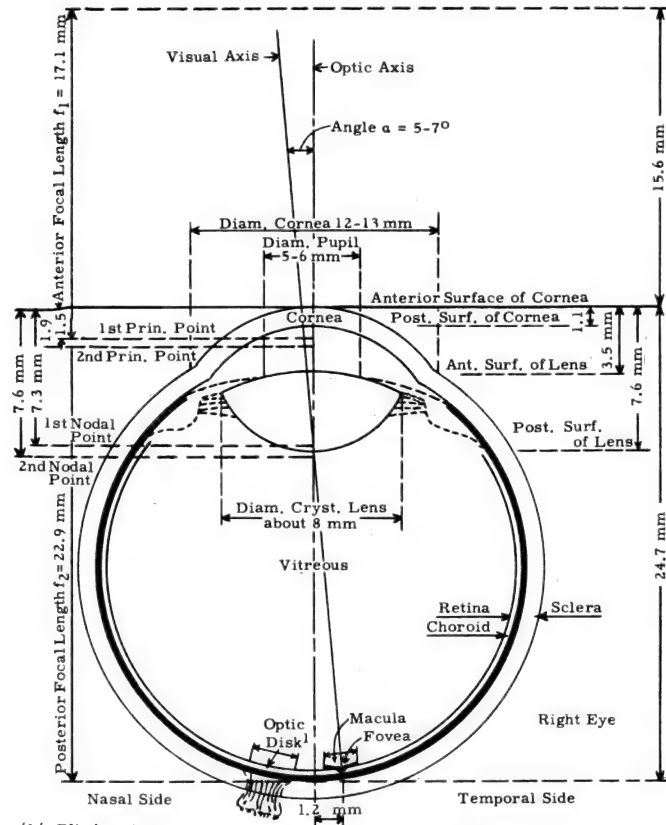
Species	Preparation, Junction, Condition	Corrected Delay msec	Temp °C
Synapses			
1 Cat (<i>Felis catus</i>)	Neuromuscular junction, soleus and other muscles.	0.55-0.65 ¹	37-39
2	Monosynaptic reflex, ventral horn motoneurons, wire electrodes.	0.3-0.45 ²	37
3	Cochlear nucleus in medulla.	0.8 ³	
4	Sympathetic ganglion.		
5	Superior cervical, synapse facilitated.	2.0 ⁴	35
6	Stellate ganglion, in situ.	3.0-4.0 ²	37-39
7	Cockroach (<i>Periplaneta americana</i>)	0.6-1.5	
8	Crayfish (<i>Cambarus</i> sp)		
9	First synapse in proprioceptive pathway		
10	Exposed ventral ganglia.	3.5-4.5 ⁵	
11	Crayfish (<i>C. clarkii</i>)	<0.1	
12	Lateral giant fibers, segmental, septal synapse.	0.5	
13	Lateral giant fibers, commissural synapse.	0.6	
14	Ipsilateral medial giant to 3rd root motor fiber, slightly fatigued.	0.1 ⁵	24
15	Earthworm (<i>Lumbricus terrestris</i>)	0.8	22.5
16	Frog (<i>Rana</i> sp)	0.8-6.5	16
17	Plume worm (<i>Protula intestinum</i>)	0.6-7+	16
18	"Quasi-artificial" jumping between giant fibers, fresh to fatigued.	0.5-0.9 ⁶	37
19	Trochlear motoneurons.	<2.5 ⁵	
20	Mesentery nerve net, through-conduction pathway	0.25	20-22
21	Shrimp, ghost (<i>Callinassa californiensis</i>)		
22	Last abdominal ganglion, giant central fiber to motor fibers in telson	33.0	7.6
23	Slug (<i>Ariolimax columbianus</i>)	19.0	21.8
24	Squid (<i>Loligo opalescens</i>)	0.5	24
25	Turtle (<i>Pseudemys</i> sp)		
26	Superior cervical ganglion	8.0 ⁷	
27	B-fibers, pre- and post-ganglion.	25.0 ⁷	
28	C-fibers, pre- and post-ganglion.		
Artificial Synapses			
29	Cat (<i>Felis catus</i>)	0.1-0.3 ⁸	
30	Cut end of nerve, A-fibers, motor to sensory.	0.1-0.3 ⁹	
31	Cut end of dorsal columns of spinal cord, dorsal root to dorsal root.	7+	
32	Crab (var. spp)		
33	Two isolated nerves or fibers in contact.		
34	Cuttlefish (<i>Sepia officinalis</i>)		
35	Two isolated nerves or fibers in contact.		
36	Giant fibers, normal or citrated.	2.5 ¹⁰ -5.0	
37	Citrated, rhythmic subthreshold activity.	>40.0 ¹⁰	
38	Earthworm (<i>lumbricus terrestris</i>)	5+	
Mechanoreceptors			
39	Cat (<i>Felis catus</i>)	0.5-1.5 ⁸	
40	Pacinian corpuscle, single mesenteric.	<105, 10, 11	
41	Baroreceptors in carotid body, single fibers.	0.6-0.8	
42	Auditory nerve spikes, click stimulus.	0.5-1.5	
43	Crayfish (<i>Cambarus</i> sp)	0.7-14.6 ⁵	20.6-29.6
44	Frog (<i>Rana temporaria</i>)	0.15	
45	Touch receptors, dorsal skin.		
46	Guinea pig (<i>Cavia porcellus</i>)		
47	Cochlear microphonic to action potential.		
Radiation Receptors			
48	Cat (<i>Felis catus</i>)	4.0	
49	Electroretinogram (ERG), a-wave.	25-80 ⁴ , 10	
50	ERG, b-wave.	720-16,000	20
51	Clam (<i>Mya arenaria</i>)	77-750	
52	Crab, horseshoe (<i>Limulus polyphemus</i>)	70	
53	Spikes in optic nerve, near-maximal and near-threshold stimuli.	10 ¹² -55	25-28
54	ERG, intracellular electrode in ommatidial receptor.	6,0 ¹⁰ , 12	
55	ERG, near-maximal light flash.	28-120	
56	Fly (<i>Calliphora erythrocephala</i>)	9.3 ¹² -59.6	
57	ERG, near-maximal stimuli, compound eye.		
58	Frog (<i>Rana</i> sp)		
59	ERG, a-wave, isolated eye, maximal stimuli.		
60	Grasshopper (<i>Melanoplus differentialis</i>)		
61	ERG, near-maximal stimuli.		
62	Pigeon (<i>Columba</i> sp)	8.0	
63	ERG, a-wave.	15-50 ¹³	23
64	Rattlesnake (<i>Crotalus viridis</i>)	6 ¹² -20	22
65	Infrared receptor in facial pit organ.		
66	Slater, rock (<i>Ligia occidentalis</i>)		
67	ERG, compound eye, near-maximal stimuli.		
Crest Times			
68	Cat (<i>Felis catus</i>)	0.8 ¹³	37-39
69	Neuromuscular junction, circulated soleus strip.	0.6-1.0 ¹⁴	36-38
70	Spinal cord, ventral horn motoneuron, internal electrode.	3.0	17
71	Crab (var. spp)		
72	Various leg muscles, end-plate potential.		
73	Frog (<i>Rana temporaria</i>)		
74	Neuromuscular junction.		
75	Isolated skeletal muscle, internal electrode.	1.2 ¹³	20
76	Isolated fiber; external microelectrode on single end-plate.	0.5	
77	Frog (<i>Hyla aurea</i>)	1.0	16
78	Plume worm (<i>Protula intestinum</i>)	10-20	37-39
79	Giant synapse in brain, in situ.	25-35 ¹³	35
80	Rabbit (<i>Oryctolagus cuniculus</i>)		
81	Sympathetic ganglion, stellate, in situ.		
82	Sympathetic ganglion, isolated superior cervical.		

/1/ Decerebrate or nembutal. /2/ Nembutal. /3/ Avertin. /4/ Decerebrate. /5/ Uncorrected for conduction time. /6/ Decorticate. /7/ Measured from 1st reversal of sign of prespike; conduction-time correction not stated. /8/ Decerebrate or chloralose. /9/ Dial. /10/ Measured from illustrations. /11/ Chloralose-urethane. /12/ Probably minimum, i.e. light intensity probably nearly maximal. /13/ Curarized. /14/ Pento-barbitone.

290. THE VISUAL MECHANISM: MORPHOLOGY AND PHYSIOLOGY

(For definition of terms, see Glossary, Part XVI.)

Part I: ANATOMY OF THE EYE: MAN



/1/ Blind spot.

Part IV: DIMENSIONS OF EYEBALL: VERTEBRATES

Values are millimeters.			
Animal	Horizontal	Vertical	Sagittal
1 Man	24.0	23.5	24.0
2 Elephant, Indian	41.0	40.0	35.1
3 Fox	16.0	16.0	15.4
4 Gorilla	22.5	22.5	22.5
5 Horse	50.5	50.5	45.5
6 Lion	35.0		37.5
7 Mole	1	1	1
8 Swine	26.9	26.0	24.8
9 Whale, great blue	145	129	107
10 Goose	12	12	10
11 Alligator	20.0	20.0	
12 Iguana	16.6	13.7	14.6
13 Frog	5.8	5.6	5.3
14 Bowfin	12.5	12	10
15 Herring	11.5	11.5	7.5
16 Lamprey	4.9	4.5	4.0

Part V: RETINA: MAN

Section 1: General Characteristics

Designation	Cones	Rods
1 20 min angle = 100 μ		
2 Thickness, extrafovea, 300 μ		
3 Thickness, fovea, 125-135 μ		
4 Approx. diam. of fovea, 300 μ		
5 No. nerve fibers in optic nerve, 800,000-1,000,000		
6 No. receptors for each eye	7 million	125 million
7 Total receptors in fovea	12,000	0
8 Diam. of receptor, μ	1.0-5.0	1.0-2.5
9 Photochemical substance (Iodopsin) ¹		Rhodopsin
10 Wave length for max. sensitivity, μ	0.56	0.51
11 Approx. range of response, μ	0.4-0.75	0.40-0.65
12 Sensation	Chromatic	Mono-chromatic
13 Absolute threshold, millilamberts	0.01	0.000001
14 Approx. time for dark adaptation, min	2	30

/1/ Found only in retina of chicken.

Part II: OPTICAL CONSTANTS OF EYES: MAMMALS

Values in brackets refer to state at maximal accommodation.

Constant	Eye Area or Measurement	Man	Cat	Dog	Horse	Ox	Sheep	Swine
1	Cornea	1.37	1.37	1.37	1.37	1.37	1.37	1.38
2	Aqueous humor	1.33	1.33	1.33	1.33	1.33	1.33	1.33
3	Lens capsule	1.38 ¹	1.37	1.37	1.38	1.38	1.36	1.36
4	Outer cortex, lens		1.38		1.39	1.38	1.37	1.38
5	Ant. cortex, lens			1.38	1.39	1.38	1.38	
6	Post. cortex, lens			1.38	1.39	1.38	1.38	
7	Center, lens	1.41	1.46	1.44	1.45	1.46	1.45	1.44
8	Calc. total index	1.41	1.52		1.50	1.55	1.53	1.48
9	Vitreous body	1.33	1.33	1.33	1.33	1.33	1.33	1.33
10	Radius of curvature, mm	7.7	9.5	8.7	18.7	16.8	12.7	11.0
11	Ant. surface, lens	9.2-12.2	6.7	6.5	14.0	11.3	8.9	7.2
12	Post. surface, lens	5.4-7.1	6.4	5.5	10.1	9.7	7.9	6.3
13	Distance from cornea, mm	1.2	0.8-1	0.5	1-1.5	1.5-2	0.8-1.2	1-1.2
14	Ant. surface, lens	3.5	4.5	4.8	5.5	4.4	3.0	2.8
15	Post. surface, lens	7.6	12	12	18	16	13	11
16	Retina	24.8	21	21	42	36	28	25
17	Ant. focal length	17.1						
18	Post. focal length	[14.2]						
19		22.8						
20		[18.9]						
21	1. Focus	-15.7						
22	2. Focus	[-12.4]						
23	Position of cardinal points measured from corneal surface, mm	24.4						
24	1. Principal point	[21.0]						
25	2. Principal point	1.5						
26		[1.8]						
27	1. Nodal point	1.9						
28	2. Nodal point	[2.1]						
29		7.3						
30		[6.5]						
31		7.6						
32		[6.8]						
33	Optic disk	2-5						
34	Macula	1-3						
35	Fovea	1.5						
36	Anterior chamber	2.7-4.2						

/1/ Cortex of lens and its capsule.

Part III: VOLUME OF EYEBALL AND ITS PARTS: MAMMALS

Values are milliliters; those in parentheses are ranges.

Animal	Eyeball	Lens	Anterior Chamber	Posterior Chamber	Vitreous
1 Man	5.4	0.2	0.3	0.2	3.9
2 Cat	3.9	0.5	0.6	0.3	2.8
3 Dog	4.4(1-5)	0.5	0.4	0.2	3.2
4 Horse	45(40-47)	2.8	2.4	1.6	28.8
5 Ox	32(28-44)	2.2	1.7	1.5	20.9
6 Rabbit	3.0	0.2	0.3	0.1	2.0
7 Sheep	12.2(8-14)	0.9	0.8	0.5	7.0
8 Swine	7.22(3-9)	0.8	0.3	0.3	5.7

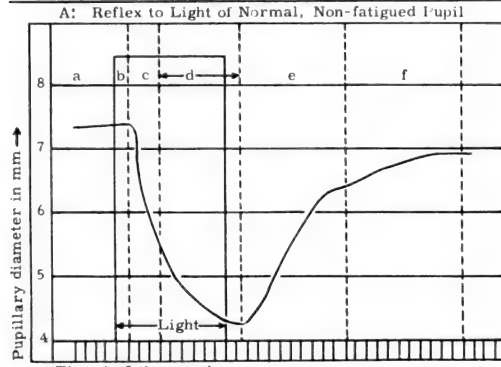
Section 2: Rod and Cone Population and Cone Acuity¹

Values in parentheses are ranges.

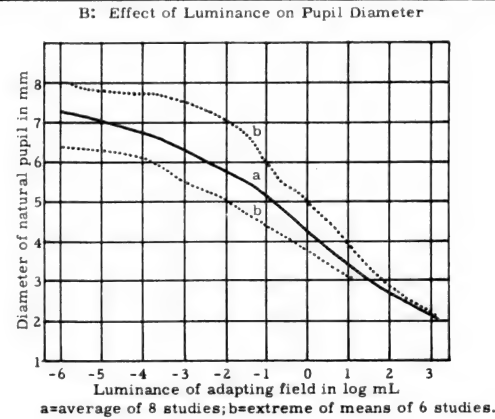
Angular Eccentricity ² degrees	Population		Visual Angle Subtended at Eye minutes
	Rods/sq mm	Cones/sq mm	
	thousands		
1 0	0	136	0.7(0.5-1.0)
2 1/4	0	84.4	0.8(0.6-1.1)
3 1/2	7.22	57.5	1.0(0.7-1.3)
4 3/4	12.4	49.1	1.1(0.8-1.5)
5 1	34.2	41.3	1.2(0.8-1.5)
6 1 1/2	53.0	29.3	1.4(0.8-2.0)
7 2	56.9	25.3	1.7(1.0-2.3)
8 6	105	12.1	4.5(1.5-6.7)
9 12	125	7.64	6.1(2.5-10)
10 20	158	7.08	10(5.0-17)
11 40	132	5.95	27.5(14-48)
12 50	108	5.79	42.5(21-72)
13 70	80.4	5.47	100(47 - X ³)
14 90	57.7	6.84	X ³ (126 - X ³)

/1/ At or near horizontal meridian. /2/ From fovea. /3/ Unmeasurably poor acuity.

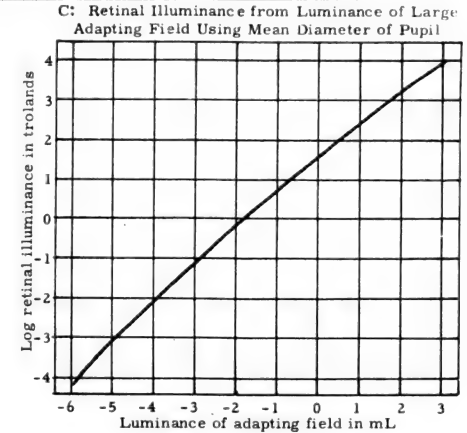
Part VI: PUPIL: MAN



a = dark adapted pupillary diameter; b = latency period for contraction; c = first (fast) phase of contraction; d = second (slower) phase of contraction; e = first (faster) phase of redilation; f = second (slower) phase of redilation.



a = average of 8 studies; b = extreme of means of 6 studies.



D: Accommodation
Values in parentheses are ranges.

Age yr	Amplitude Diopter
10	14(11.5-16.5)
12	12.4(9.9-14.9)
14	10.8(8.5-13.3)
16	9.4(7.4-11.7)
18	8.2(6.3-10.2)
20	7.0(5.5-8.5)
22	5.8(4.3-7.3)
24	4.8(3.7-6.1)
26	4.1(3.1-5.1)
28	3.3(2.3-4.3)
30	2.5(1.7-3.0)
32	1.8(1.3-2.3)
34	1.2(0.7-1.7)
36	0.8(0.45-1.1)
38	0.4(0.15-0.8)
40	0.2(<0.1-0.5)

1/1 Subjective measurements.

A: Relative Effectiveness of Different Wave Lengths 100 = maximal sensitivity or effectiveness						
Wave Length $m\mu$	Color Spectrum	Rods	Cones	Scotopic	Photopic	
1 400	Violet	4	0	3	0	
2 450		40	5	37	6	
3 500		100	33	97	36	
4 511				100	60	
5 550	Green	55	100	60	99	
6 554				41	100	
7 600	Yellow	7	65	10	64	
8 650		Slight	13	1	14	
9 700	Red	0	Slight	0	2	

C: Spectral Sensitivities of Rods and Cones Values are log sensitivity (log I/threshold) at various wave lengths in a 1° circular field exposed for flashes of 1/25 sec.						
Wave Length $m\mu$	Foveal ¹	Normal Eyes		Aphakic ¹ Eyes		
		Rods ²	Cones ¹	Rods ²	Cones ²	
1 365	5.401	2.042	6.95	2.62	2.42	
2 405	3.806	0.427	3.64	1.05	2.88	
3 436	2.643	1.675	2.67	1.48	1.22	
4 492	1.288	2.295	1.25	0.00		
5 546	1.980	2.095	1.65	1.78	0.01	
6 578	1.966	1.375	1.59	1.12	1.90	
7 621	1.626	0.038	1.27	3.87	1.63	
8 691	3.840	3.635	3.43	5.39	3.87	
9 713	3.048	4.787	4.59	6.52	3.11	
10 750	4.072	5.890	5.68	7.68	4.18	

1/1 Values are relative to foveal maximum sensitivity. 2/2 Values are relative to maximal sensitivity of aphakic dyes.

Part VII: LUMINOSITY

B: Relative Luminosities														
Wave Length mμ	Photopic (CIE ¹ 1924)	Mesopic (Weaver 1949)								Scotopic (CIE ¹ 1951 for Young Eyes)				
		Logarithm of Adapting Luminance, Ft-L												
		-0.5	-1.0	-1.5	-2.0	-2.5	-3.0	-3.5	-4.0					
1 380	0.00004		0.0001	0.0002	0.0008	0.0015	0.0025	0.0034	0.0045	0.00059				
2 400	0.0004	0.0004	0.0008	0.0022	0.0059	0.0098	0.0147	0.0185	0.0228	0.00929				
3 420	0.004	0.0044	0.0069	0.0152	0.0280	0.0427	0.0580	0.0690	0.0820	0.09661				
4 440	0.023	0.0240	0.0300	0.0496	0.0850	0.123	0.160	0.183	0.216	0.3281				
5 460	0.060	0.0627	0.0775	0.127	0.202	0.277	0.339	0.376	0.423	0.5672				
6 480	0.139	0.146	0.180	0.288	0.432	0.540	0.604	0.649	0.685	0.7931				
7 490	0.208	0.220	0.274	0.426	0.592	0.687	0.734	0.782	0.814	0.9029				
8 500	0.323	0.340	0.416	0.603	0.744	0.826	0.864	0.902	0.930	0.9818				
9 510	0.503	0.524	0.617	0.766	0.876	0.935	0.962	0.977	0.992	0.9966				
10 520	0.710	0.726	0.792	0.894	0.965	0.992	0.999	0.988	0.974	0.9352				
11 530	0.862	0.872	0.910	0.972	1.000	0.982	0.951	0.924	0.883	0.8110				
12 540	0.954	0.959	0.979	1.000	0.969	0.909	0.842	0.796	0.744	0.6497				
13 550	0.995	0.997	1.000	0.971	0.886	0.785	0.698	0.642	0.583	0.4808				
14 560	0.995	0.992	0.973	0.898	0.760	0.640	0.543	0.478	0.419	0.3288				
15 570	0.952	0.944	0.907	0.782	0.617	0.485	0.384	0.330	0.281	0.2076				
16 580	0.870	0.860	0.802	0.648	0.468	0.340	0.259	0.218	0.182	0.1212				
17 590	0.757	0.742	0.673	0.509	0.333	0.227	0.166	0.137	0.112	0.06548				
18 600	0.631	0.616	0.544	0.374	0.224	0.145	0.101	0.0830	0.0670	0.03315				
19 610	0.503	0.490	0.416	0.257	0.142	0.0870	0.0600	0.0488	0.0388	0.01593				
20 620	0.381	0.366	0.296	0.168	0.0845	0.0504	0.0344	0.0280	0.0225	0.00737				
21 630	0.265	0.250	0.197	0.102	0.0480	0.0282	0.0194	0.0156	0.0127	0.00334				
22 640	0.175	0.162	0.122	0.0590	0.0270	0.0146	0.0107	0.0085	0.0070	0.00150				
23 650	0.107	0.0990	0.0710	0.0327	0.0147	0.0084	0.0058	0.0046	0.0037	0.00068				
24 660	0.061	0.0560	0.0390	0.0174	0.0078	0.0045	0.0031	0.0025	0.0020	0.00031				
25 680	0.017	0.0153	0.0103	0.0046	0.0022	0.0014	0.0009	0.0007	0.0006	0.000072				
26 700	0.0041	0.0038	0.0026	0.0012	0.0006	0.0003	0.0002	0.0002	0.0001	0.000018				
27 720	0.0010	0.0010	0.0007	0.0003	0.0001					0.000005				
28 740	0.0003	0.0002	0.0002							0.000001				
29 750	0.0001	0.0001								0.0000008				

1/1 Standard values adopted by the Commission Internationale de l'Eclairage.

290. THE VISUAL MECHANISM: MORPHOLOGY AND PHYSIOLOGY (Continued)

(For definition of terms, see Glossary, Part XVI.)

Part VIII: COLOR

A: Tristimulus Values of the Spectrum

Values represent the magnitudes of each of the 3 standard primaries necessary to match the given spectral light. These primaries are imaginary; for convenience, \bar{x} corresponds to the overall luminosity function of the standard observer, but, as an approximation, \bar{x} may be regarded as red, \bar{y} as green, and \bar{z} as blue.

	Wave Length $m\mu$	\bar{x}	\bar{y}	\bar{z}		Wave Length $m\mu$	\bar{x}	\bar{y}	\bar{z}
1	380	0.0014	0.0000	0.0065	31	585	0.9786	0.8163	0.0014
2	400	0.0143	0.0004	0.0679	32	590	1.0263	0.7570	0.0011
3	410	0.0435	0.0012	0.2074	33	595	1.0567	0.6949	0.0010
4	420	0.1344	0.0040	0.6456	34	600	1.0622	0.6310	0.0008
5	430	0.2839	0.0116	1.3856	35	605	1.0456	0.5668	0.0006
6	440	0.3483	0.0230	1.7471	36	610	1.0026	0.5030	0.0003
7	450	0.3362	0.0380	1.7721	37	615	0.9384	0.4412	0.0002
8	460	0.2908	0.0600	1.6692	38	620	0.8544	0.3810	0.0002
9	470	0.1954	0.0910	1.2876	39	625	0.7514	0.3210	0.0001
10	480	0.0956	0.1390	0.8130	40	630	0.6424	0.2650	
11	485	0.0580	0.1693	0.6162	41	635	0.5419	0.2170	
12	490	0.0320	0.2080	0.4652	42	640	0.4479	0.1750	
13	495	0.0147	0.2586	0.3533	43	645	0.3608	0.1382	
14	500	0.0049	0.3230	0.2720	44	650	0.2835	0.1070	
15	505	0.0024	0.4073	0.2123	45	655	0.2187	0.0816	
16	510	0.0093	0.5030	0.1582	46	660	0.1649	0.0610	
17	515	0.0291	0.6082	0.1117	47	665	0.1212	0.0446	
18	520	0.0633	0.7100	0.0782	48	670	0.0874	0.0320	
19	525	0.1096	0.7932	0.0573	49	675	0.0636	0.0232	
20	530	0.1655	0.8620	0.0422	50	680	0.0468	0.0170	
21	535	0.2257	0.9149	0.0298	51	685	0.0227	0.0082	
22	540	0.2904	0.9540	0.0203	52	700	0.0114	0.0041	
23	545	0.3597	0.9803	0.0134	53	710	0.0058	0.0021	
24	550	0.4334	0.9950	0.0087	54	720	0.0029	0.0010	
25	555	0.5121	1.0002	0.0057	55	730	0.0014	0.0005	
26	560	0.5945	0.9950	0.0039	56	740	0.0007	0.0003	
27	565	0.6784	0.9786	0.0027	57	750	0.0003	0.0001	
28	570	0.7621	0.9520	0.0021	58	760	0.0002	0.0001	
29	575	0.8425	0.9154	0.0018	59	770	0.0001	0.0000	
30	580	0.9163	0.8700	0.0017	60	775	0.0000	0.0000	

E: Wave Length Discrimination¹

Values are given in $m\mu$ for λ (wave length) and $\Delta\lambda$ (just noticeable difference in wave length, averaged from $\Delta\lambda$'s at graduated stimulus intensities).

	λ	$\Delta\lambda$		λ	$\Delta\lambda$		λ	$\Delta\lambda$
1	430	6.5	15	515	2.4	29	585	1.4
2	435	5.0	16	520	2.7	30	590	1.3
3	440	3.8	17	525	2.9	31	595	1.3
4	445	3.3	18	530	3.1	32	600	1.4
5	450	3.5	19	535	3.2	33	605	1.5
6	460	3.3	20	540	3.1	34	610	1.6
7	470	2.5	21	545	2.9	35	615	1.7
8	475	2.2	22	550	2.7	36	620	1.9
9	480	1.8	23	555	2.4	37	625	2.2
10	490	1.6	24	560	2.2	38	630	2.5
11	495	1.6	25	565	1.9	39	635	3.0
12	500	1.7	26	570	1.7	40	640	3.6
13	505	1.8	27	575	1.6	41	645	4.5
14	510	2.0	28	580	1.5	42	650	5.9

^{1/1} Monocular observations by 5 subjects (with normal color vision) of matching bipartite field at 2°. Illumination averaged 70 photons with a dark surround; an artificial pupil had 1.016mm diameter.

B: Classification and Characteristics of Abnormal Color Vision Systems

Type ¹	Designation	Common Name	Discrimination Possible	No. of Lights to Match Spectrum	Neutral Points	Appearance of Spectrum	λ ² of Max. Luminosity, $m\mu$	Saturation Characteristics
1	Mono-chromatic	Achroma-topsia	Total color blindness	Light-dark	All	Achromatic	Red mono-chromats 510 ³ (cone mono-chromats 560)	0 (Throughout spectrum)
2	Dichro-matic	Prota-nopia	Red-green blind	Light-dark, yellow-blue	493	Blue (short λ)	540	0 at neutral point;
3		Deuter-anopia	Yellow-blue blind	Light-dark, red-green	497	Yellow (long λ)	560 ⁴	↑ toward long and short ends of spectrum
4		Trita-nopia	Yellow-blue blind	Light-dark, red-green	572	Green(short λ) Red (long λ)	560	
5	Anomalous trichromatic	Prota-nomaly	Red-green weak	Light-dark; yellow-blue; red-green weak	None	Intermediate between normal and respective dichromatic types	540 ⁵	Intermediate between normal and respective dichromatic types
6		Deuter-anomaly	Yellow-blue weak	Light-dark; red-green; yellow-blue weak			560 ⁴	
7		Trita-nomaly	Yellow-blue weak	Light-dark; red-green; yellow-blue weak				

^{1/1} According to number of components (lights required to match spectrum). ^{2/2} Wave length. ^{3/3} As in dark-adapted normals. ^{4/4} Similar to normals. ^{5/5} Deficient at long wave lengths.

C: Incidence of Color Defectiveness: European-American Males

Values are percentages of populations.

Total	Degree of Color Defectiveness			Ratio Male to Female
	Anomalous Trichromats	Dichromats	Mono-chromats	
	8.2	5.8	2.4	
Type of Color Defectiveness	Protans 2.2	Protanomalous 1.0	Protanopes 1.2	16:1
	Deutans 6.0	Deuter-anomalous 4.8	Deuteranopes 1.2	
	Tritans 0.00020	Tritanomalous 0.00015	Tritanopes 0.00005	
				3:2

^{1/1} (Estimated) rod 0.004; cone 0.00001.

D: Incidence of Defective Color Vision: Various Populations

Values are per cent failing Ishihara¹ test.

Population	Male	Female
U. S. A.	6.8-9.7	0.2-1.3
European, Caucasian (Brit., Scot., Norway, Ger.)	7.5-8.0	0.4-0.6
Chinese	4.0-6.9	0.4-1.7
Japanese	2.4-6.9	0.35
American Negro	3.9	0.2
American Indian	1.1-2.0	0-0.7
Mexican	2.3	0.5

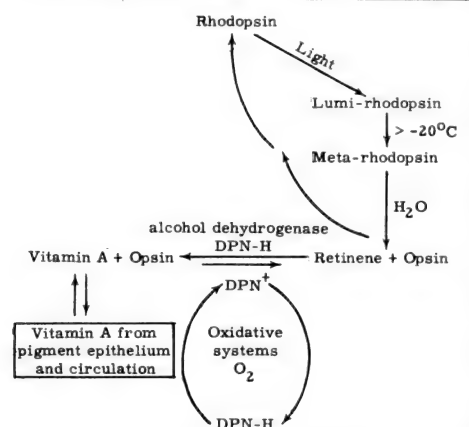
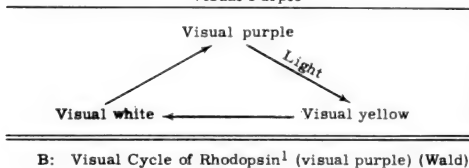
^{1/1} Criterion of failure: 2 or more plates miscalled on 5th edition Ishihara, or equivalent.

F: Color Vision: Animals.

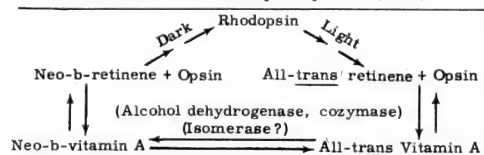
Animal	Predominant Retinal Elements	Wave Length Discrimination	Spectral Range	Probable No. Primary Colors
1 Man, chimpanzee, rhesus monkey	Rods, cones	1-2 $m\mu$ at optimal λ	400-700 $m\mu$, approximately	3
2 Cebus monkey	Rods, cones	Good except at yellow (589 $m\mu$) and longer	↓ toward long λ 's	2
3 Cat, cow, dog, mouse, rabbit	Rods	Weak or absent	↓ toward long λ 's	Unknown
4 Chicken, pigeon	Cones	Equivalent to man	Slight shift toward long λ 's	3
5 Turtle (Clemmys caspica)	Cones	Very good	Equivalent to man	3
6 Fish (Phoxinus laevis)	Rods, cones	Very good	Possible shift toward short λ 's	3
7 Calliphora	Compound eye	Fair	Shift toward long λ 's	Unknown
8 Dronefly (Eristalis tenax)	Compound eye	Present	Unknown	Unknown
9 Honey bee, bumble bee, hawkmoth, Vanessa butterfly	Compound eye	Fair	Shift toward short λ 's	Unknown
10 Papilionid and Pieridid butterflies	Compound eye	Fair	Range equivalent to man	Unknown

Part IX: PHOTOCHEMISTRY OF VISION

A: Theory (Kühne) of Decomposition and Regeneration of Visual Purple

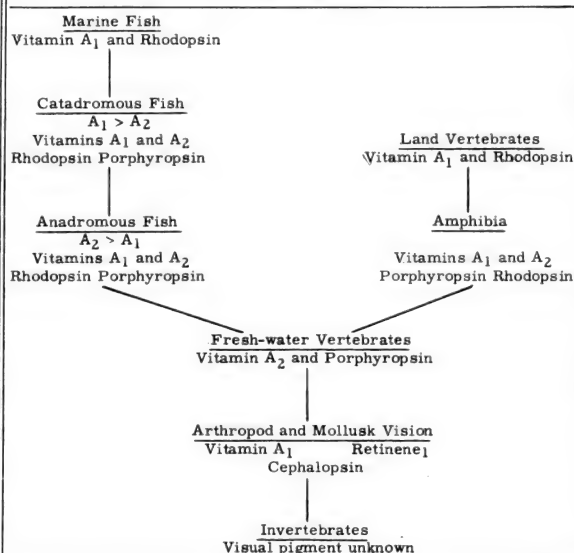


/1/ The bulk of the cycle lies within the outer segments of the retinal rods, but it is supplemented with vitamin A, respiratory factors and oxygen from the pigment epithelium and the blood circulation.

C: Participation of cis-trans Isomers of Vitamin A and Retinene in the Rhodopsin System¹ (Wald)

/1/ Bleaching of rhodopsin yields all-trans retinene. This must be isomerized to the mono-cis, neo-b configuration before it can regenerate rhodopsin. Alternatively, having been reduced to all-trans vitamin A, the latter must be isomerized to neo-b-vitamin A, before it can take part again in rhodopsin synthesis. Rod vision depends therefore upon the continuous stereoisomerization of all-trans retinene or vitamin A, to provide new supplies of the neo-b-isomer.

D: Visual Systems

E: Vitamin A Type and Maximum Spectral Sensitivity in Retinas¹

Organism	Absorptive Max. of Vis. Pigment $m\mu$	Proportion ² of Vit. A ₁ to Vit. A ₂
1 Man	497	A ₁ present
2 Cattle	498	100:0
3 Goat	about 500	100:0
4 Guinea pig	about 500	100:0
5 Rat	498	100:0
6 Sheep	498	100:0
7 Chicken	about 500	
8 Owl (Syrnium aluco)	500	A ₁ present
9 Frog (Rana catesbeiana)	502	A ₂ present
10 Frog, tadpoles (R. catesbeiana)	520	0:100
11 Carp (Cyprinus carpio)	522	29:71
12 Chinook (Oncorhynchus tshawytscha)	510-515	100:0
13 Dogfish, smooth (Galeorhinus laevis)	500	100:0
14 Dogfish, spiny (Squalus acanthias)	500	62:38
15 Eel (Anguilla rostrata)	500	100:0
16 Haddock (Melanogrammus aeglefinus)		11:89
17 Lamprey, sea (Petromyzon marinus)	525	0:100
18 Perch, white (Morone americana)	522	0:100
19 Pickerel (Esox reticulatus)	522	18:82
20 Tautog (Tautoga onitis)	523	38:62
21 Tench (Tinca vulgaris)	510-515	100:0
22 Trout, rainbow (Salmo irideus)		
23 Whiting (Merluccius bilinearis)	500	
24 Squid (Loligo pealei)		

/1/ In scotopic vision. /2/ Not tested for homogeneity.

Part X: FLICKER-FUSION

A: Variables Affecting Critical Flicker Frequency

Stimulus Variable	Effect on Critical Flicker-Fusion ¹
1 Luminance	Proportional to log intensity of luminance source in midrange of values.
2 Stimulus area	Proportional to log area of source.
3 Light-dark cycle	Max. CFF with light-darkness ratios 1.0-0.5.
4 Surrounds of stimulating field	CFF highest when brightnesses of test fields and surrounds are equal.
5 Method of stimulation	Monocular vs. binocular: binocular \uparrow .
6 Spectral composition of source	Max. CFF at 570 $m\mu$, falling slightly in approx. symmetrical way on either side of max.
7 Retinal area	For stim. areas over 1°, max. CFF usually found 20°-40° eccentric to visual axis.
8 2 or 2+ sources in field	Usually interact: CFF \uparrow .
9 Stimulated phase relation: both eyes	Max. CFF when in phase. Reduced 2-4 cps when 180° out of phase.
10 Intermittence rate	Enhancement of apparent brightness at 8-10 cps (Bartley effect), and at 16-18 cps (Brucke effect).
11 Intersensory effects	When auditory clicks, cutaneous taps, or olfactory puffs are synchronized with visual intermittence, CFF \uparrow .

Subject Variable	Effect on Critical Flicker-Fusion ¹
12 Chronological age	CFF inversely proportional to age between 30-95 years.
13 Interindividual differences	Under same conditions, range between individuals about 12 cps.
14 Intraindividual differences	Among 9 out of 10 individuals (unchanged conditions), range of daily CFF determinations should not be over 1.5 cps.
15 Practice	May go up, down or remain unchanged.
16 Duration of observation	CFF increases during 0.1-1.0 sec of observation; constant with observations of 1-10 sec.
17 Acceleration (+)	\downarrow 2 cps with 2.8-4.8G in centrifuge.
18 Anoxia	\downarrow at simulated altitude of 10,000-18,000 ft.
19 Brain injury ²	CFF \downarrow .
20 Carbon dioxide; carbon monoxide	CFF drops rapidly with inhalation of CO ₂ or CO; permanently \downarrow after CO poisoning.
21 Refraction	CFF unchanged when glasses are worn.
22 Light vs dark adaptation	CFF \uparrow during 15 min light adaptation; \downarrow during 60 min dark adaptation.
23 Anxiety	CFF \downarrow when compared to normal state.
24 Color blindness ³	CFF \downarrow .

/1/ cps=cycles per second; max.=maximum; stim.=stimulated; \uparrow =increased; \downarrow =decreased. /2/ Or pathology. /3/ Complete.

B: Maximum Critical Flicker Frequencies

Organism	Max. CFF cps	Organism	Max. CFF cps
1 Man ¹	Rods 15; cones 61-90	12 Turtle ³	52
2 Cat ¹	Cones 50	13 Frog ¹	Cones 40
3 Dog	25 (ergs)	14 Newt ⁴	Cones 44
4 Rabbit ²	30	15 Sunfish ¹	Rods 10; cones 50
5 Buzzard ³	40 (ergs)	16 Teleost ^{1,5}	Rods 8; cones 52
6 Chicken ¹	35 (ergs)	17 Crayfish ⁶	50
7 Finch, zebra ³	57	18 Isopod ⁶	52
8 Gecko ²	27	19 Bee; wasp ⁶	300 (ergs)
9 Owl ²	21	20 Cricket ⁶	45 (ergs)
10 Pigeon ¹	40 (ergs)	21 Dragonfly ^{6,7}	61
11 Lizard ³	56	22 Fly ^{6,8}	250 (ergs)

/1/ Duplex retina. /2/ Rod retina. /3/ Cone retina. /4/ Triplex retina. /5/ Enneacanthus. /6/ Compound eye. /7/ Larva. /8/ Calliphora.

290. THE VISUAL MECHANISM: MORPHOLOGY AND PHYSIOLOGY (Concluded)

Part XI: WAVE LENGTH OF MAXIMAL SENSITIVITY¹: ANIMALS AND PLANTS

Organism	Wave Length mμ
1 Man	560
2 Cat	560
3 Guinea pig	500
4 Rat	500
5 Chicken	560-580
6 Pigeon	580
7 Snake	560
8 Tortoise	620
9 Frog	560
10 Fish, fresh-water	540-610
11 Salt-water	500
12 Crab	480-500
13 Squid	480-500
14 Bee	360 ²
15 Drosophila	360
16 Blowfly larvae	503
17 Tenebrio larvae	535
18 Mya	500
19 Balanus larvae	560-578
20 Arenicola	483
21 Volvox	494
22 Hydra	430-490
23 Eudendrium	460-480
24 Pandorina	524
25 Phacus	483
26 Ameba	430-490
27 Euglena	483
28 Green plants	465
29 Seedlings	blue
30 Avena	440
31 Phycomyces	449

/1/ Photopic conditions. /2/ Also green.

A: Following Light Adaptation to Various Brightnesses¹

Values in boxes indicate color was apparent at threshold.

400,000 Photons		38,900 Photons		19,500 Photons		3800 Photons		263 Photons	
Time min	Log B μpho ²	Time min	Log B μpho ²	Time min	Log B μpho ²	Time min	Log B μpho ²	Time min	Log B μpho ²
1	0.19	8.26	0.10	7.16	0.17	6.96	0.18	6.22	0.14
2	0.52	7.58	0.57	6.53	0.42	6.41	0.42	5.60	0.36
3	1.1	7.07	1.0	6.11	0.97	6.11	0.67	5.25	0.50
4	1.5	6.80	2.5	5.90	1.7	5.94	1.3	4.92	0.90
5	2.2	6.37	3.3	5.81	2.7	5.75	2.1	4.72	1.4
6	2.7	6.19	4.1	5.76	4.1	5.59	2.9	4.54	2.9
7	3.4	6.00	5.3	5.75	5.1	5.42	3.8	4.41	4.1
8	4.4	5.92	6.1	5.67	6.3	5.17	4.9	4.15	5.3
9	6.4	5.80	7.1	5.61	7.6	4.81	5.9	3.96	6.2
10	7.7	5.73	7.8	5.45	9.2	4.38	7.7	3.60	7.2
11	9.5	5.68	8.9	5.26	10.7	3.98	9.4	3.40	8.9
12	10.7	5.66	9.9	4.99	11.9	3.70	10.6	3.16	10.5
13	12.6	5.34	10.8	4.77	13.0	3.50	13.5	2.89	11.5
14	14.3	4.78	12.5	4.28	14.4	3.28	15.0	2.80	13.1
15	16.0	4.28	14.3	3.81	16.1	3.07	16.4	2.77	15.1
16	16.7	4.11	15.4	3.52	17.8	2.92	18.2	2.62	17.3
17	18.0	3.79	16.8	3.29	18.8	2.83	21.9	2.56	19.7
18	19.6	3.55	18.6	3.13	20.0	2.79	23.7	2.49	23.5
19	21.5	3.27	20.5	2.99	21.1	2.78	25.4	2.46	25.8
20	23.0	3.20	22.5	2.92	24.5	2.64	28.8	2.47	27.5
21	24.2	3.13	23.9	2.88	26.1	2.57			29.6
22	25.9	3.08	26.0	2.79	27.7	2.57			
23	28.5	2.97	29.3	2.69	29.8	2.58			
24	30.8	2.88	32.0	2.55					
25	33.4	2.84							
26	36.0	2.78							
27	38.6	2.72							

/1/ Values, from one observer, are least amounts necessary to produce response.

Adapting field: 30° in diameter, white light, fixated 30° nasally on the retina, exposed for 2 minutes. Test field: 5° diameter containing a centered opaque cross 30° wide, violet light, fixated 30° nasally on the retina, exposed for 0.2 second.

/2/ Microphotons.

Part XII: DARK ADAPTATION: MAN

B: Time-Luminance Relation

Time in Dark min		Log Brightness ¹ millilamberts	Adapting Element
1	1	-1.5	Cones
2	1	-2.0	
3	2	-2.3	
4	3	-2.5	
5	4	-2.6	
6	5	-2.7	
7	6	-2.73	
8	7	-2.75	
9	8	-3.3	
10	9	-3.8	
11	10	-4.2	Rods
12	15	-5.1	
13	20	-5.3	
14	25	-5.5	
15	30	-5.6	

/1/ Values are least amount necessary to produce positive responses.

/2/ Adaptation curve breaks caused by change from cone to rod vision.

C: Relative Sensitivity of Dark-adapted Eye

Wave Length mμ	Relative Sensitivity ¹	
	Periphery ²	Fovea
1	400	-20
2	450	-10
3	500	-3
4	525	0
5	550	0
6	600	-4
7	650	-10
8	700	-27
9	750	-40

/1/ In decibels. /2/ 8° above fixation.

A: Visual Phenomena as Functions of Luminance: Man

Log B ¹ mL	Pupil Diameter mm	Visual Acuity ²	Intensity Discrimination, ΔB/B
1	-6.0	7.17	
2	-5.0	7.02	
3	-4.0	6.78	0.08
4	-3.5		0.11
5	-3.0	6.37	0.13
6	-2.5		0.19
7	-2.0	5.80	0.29
8	-1.5		0.52
9	-1.0	5.10	0.80
10	-0.5	4.74	1.14
11	0	4.39	1.48
12	0.5	4.05	1.74
13	1.0	3.64	2.0
14	1.5	3.19	2.15
15	2.0	2.77	2.22
16	2.5	2.43	2.25
17	3.0	2.09	2.26
18	3.5		0.037

/1/ White light. /2/ An acuity of 1.00 represents a visual angle of a 1' arc.

B: Visual Acuity and Illumination: Man

Test object: Landolt's ring.

Red (λ= 670 mμ)		Blue (λ= 490 mμ)		White	
Log I photons	Log V.A. ¹	Log I photons	Log V.A. ¹	Log I photons	Log V.A. ¹
1	-2.88	-1.43	-4.87	-1.47	-3.44
2	-2.55	-1.19	-4.09	-1.07	-2.87
3	-2.25	-0.95	-3.79	-0.95	-2.42
4	-1.85	-0.66	-2.97	-0.78	-2.13
5	-1.53	-0.44	-2.32	[-0.65]	-1.85
6	-1.23	-0.27	-2.02	[-0.56]	-1.85
7	-0.81	-0.10	-1.72	[-0.48]	-1.45
8	0.49	0.02	-1.72	-0.73	-1.45
9	-0.19	0.12	-1.28	[-0.38]	-1.16
10	0.14	0.21	-1.28	-0.46	-1.16
11	0.46	0.26	-0.97	[-0.28]	-0.88
12	1.08	0.30	-0.67	-0.14	-0.88
13	1.71	0.33	-0.25	0.02	-0.19
14	2.43	0.36	0.36	0.21	0.09
15	3.15	0.37	1.19	0.30	0.77
16	3.77	0.38	1.83	0.35	1.50
17			2.44	0.37	2.47
18			3.18	0.39	3.44

/1/ Underlined values are rod determinations in a subjectively colorless field; those in brackets, with parafoveal rod and cone vision in a colored field; balance of values, with foveal cone vision in a colored field.

C: Resolving Power of Eyes

Organism	Test Object	Background Illumination	Minimum Resolvable Angle
1 Man	Dark square	Bright sky	14.2 sec
2	Dark line	0.006 μL	10-11 min
3	Fine wire	Bright sky	0.43 sec
4	Grating	0.006 μL	20-30 min
5	Grating	30.2 mL	0.5-1 min
6 Cat	Grating	37.8 ft. cand.	0.45-1 min
7 Monkey	Grating	3.85 mL	0.95 min
8 Rat, albino	Grating		56 min
9 pigmented	Grating		26 min
10 Chick	Grating	3.85 mL	4.07 min
11 Pigeon	Grating	14.4 ft. cand.	0.38-0.5 min
12 Lizard	Grating	Lowest I ¹	0.5-1°
13	Grating	Highest I ¹	1.3-11.5 min
14 Frog	Pendulum		29.4 min
15 Crab, fiddler	Dark line	263 ft. cand.	3.87°
16 Bee	Grating	100 mL	0.9-1.0°
17	2 cm square ²	Daylight	2.8°
18 Fly, fruit	Dark line	14.6 mL	9.28°

/1/ Intensity.

/2/ At 40 cm.

D: The Stiles-Crawford Effect¹Rays entering the eye near the edge of the pupil are less effective than rays entering near the center. Their relative effectiveness is denoted by η : $\eta = 1 - 0.0850 x^2 + 0.0020 x^4$, where x is the distance (mm) from the center of the pupil.

Distance mm	η for Single Ray	Pupil Diameter mm	η for Light Filling Entire Pupil
1	0	1.000	
2	0.5	0.980	
3	1.0	0.917	2.0
4			2.5
5	1.5	0.819	3.0
6			3.5
7	2.0	0.692	4.0
8			4.5
9	2.5	0.548	5.0
10			5.5
11	3.0	0.397	6.0
12			6.5
13	3.5	0.260	7.0
14			7.5
15	4.0	0.152	8.0

/1/ Occurs only in cone vision.

Part XIV: CONVERSION FACTORS FOR BRIGHTNESS (LUMINANCE AND LUMINOUS EMITTANCE) UNITS
Value in unit in left hand column times the conversion factor equals the value in unit shown at the top of the column.

Units	C/sq mm	C/sq cm	C/sq m	Stilb (H)	C/sq in.	C/sq ft	L	mL	μ L	$m\mu$ L	Apostilb(H)	Ft-L	Photons ¹
1 Candles per square millimeter	1	1×10^2	1×10^6	1.111×10^2	6.452×10^2	9.290×10^4	3.142×10^2	3.142×10^5	3.142×10^8	3.142×10^{11}	3.491×10^6	2.919×10^5	7.854×10^5
2 Candles per square centimeter (C.I.E. Stilb)	1×10^{-2}	1	1×10^4	1.111	6.452	9.290×10^2	3.142	3.142×10^3	3.142×10^6	3.142×10^9	3.491×10^4	2.919×10^3	7.854×10^3
3 Candles per square meter	1×10^{-6}	1×10^{-4}	1	1.111×10^{-4}	6.452×10^{-4}	9.290×10^{-2}	3.142×10^{-4}	3.142×10^{-1}	3.142×10^2	3.142×10^5	3.491	2.919×10^{-2}	7.854×10^{-1}
4 Hefner candles per square centimeter (Stilb (H))	9.0×10^{-3}	9.0×10^{-1}	9.0×10^3	1	5.806	8.361×10^2	2.828	2.828×10^3	2.828×10^6	2.828×10^9	3.142×10^4	2.627×10^3	7.069×10^3
5 Candles per square inch	1.550×10^{-3}	1.550×10^{-1}	1.550×10^3	1.722×10^{-1}	1	1.440×10^2	4.869×10^{-1}	4.869×10^2	4.869×10^5	4.869×10^8	5.411×10^3	4.524×10^2	1.217×10^3
6 Candles per square foot	1.076×10^{-5}	1.076×10^{-3}	1.076×10	1.196×10^{-3}	6.944×10^{-3}	1	3.382×10^{-3}	3.382	3.382×10^3	3.382×10^6	3.758×10	3.142	8.454
7 Lamberts (equivalent centimeter candles, apparent lumens per square centimeter)	3.183×10^{-3}	3.183×10^{-1}	3.183×10^3	3.537×10^{-1}	2.054	2.957×10^2	1	1×10^3	1×10^6	1×10^9	1.111×10^4	9.290×10^2	2.500×10^3
8 Millilamberts	3.183×10^{-6}	3.183×10^{-4}	3.183	3.537×10^{-4}	2.054×10^{-3}	2.957×10^{-1}	1×10^{-3}	1	1×10^3	1×10^6	1.111×10	9.290×10^{-1}	2.500
9 Microlamberts	3.183×10^{-9}	3.183×10^{-7}	3.183×10^{-3}	3.537×10^{-7}	2.054×10^{-6}	2.957×10^{-4}	1×10^{-6}	1×10^{-3}	1	1×10^3	1.111×10^{-2}	9.290×10^{-4}	2.500×10^{-3}
10 Milli-microlamberts (micro-millilamberts)	3.183×10^{-12}	3.183×10^{-10}	3.183×10^{-6}	3.537×10^{-10}	2.054×10^{-9}	2.957×10^{-7}	1×10^{-9}	1×10^{-6}	1×10^{-3}	1	1.111×10^{-5}	9.290×10^{-7}	2.500×10^{-6}
11 Apostilb (Hefner lumens per square foot)	2.864×10^{-7}	2.864×10^{-5}	2.864×10^{-1}	3.183×10^{-5}	1.848×10^{-4}	2.661×10^{-2}	9.0×10^{-5}	9.0×10^{-2}	9.0	9.0×10^4	1	8.360×10^{-2}	2.249
12 Foot-lamberts (equivalent foot candles; apparent foot candles; apparent lumens per square foot)	3.426×10^{-6}	3.426×10^{-4}	3.426	3.807×10^{-4}	2.210×10^{-3}	3.183×10^{-1}	1.076×10^{-3}	1.076	1.076×10^3	1.076×10^6	1.196×10	1	2.691
13 Photons ²	1.273×10^{-6}	1.273×10^{-4}	1.273	1.414×10^{-4}	8.213×10^{-4}	1.183×10^{-1}	4.000×10^{-4}	4.000×10^{-1}	4.000×10^2	4.000×10^5	4.444×10	3.716×10^{-1}	1

/1/ In converting measures of brightness into photons, it is necessary to multiply the conversion factor by the square of the pupil diameter in millimeters. /2/ In converting photons to measures of brightness, it is necessary to divide the conversion factor by the square of the pupil diameter in millimeters.

Part XV: MISCELLANEOUS

A: Characteristic Luminances
Values in parentheses are ranges.

Specification	Luminance ft-L ¹
1 Noon sun on snow	10,000
2 Hazy sky	1,000
3 Foliage in landscape	(100-400)
4 Living room walls	(7-10)
5 Television screens in homes	(3.5-10)
6 Motion pictures (theater)	1.6(0.4-5)
7 Drive-in	0.7(0.1-2.2)
8 Photopic vision	>0.01
9 Mesopic vision	(0.001-0.01)
10 Scotopic vision	<0.001
11 Cones take over	0.006±
12 Rods take over	0.008±
13 Lower limit of useful color vision	0.019±
14 Night automobile driving	(0.003-4)
15 Asphalt roads	(0.045-1.1)
16 Cement roads	(0.08-3.2)
17 Pedestrian on road	(0.012-0.35)
18 Moonlight	0.01
19 Clear starlight, no moon	0.0001
20 Hazy starlight, no moon	0.00001
21 Threshold	0.00001

B: Color Temperatures

Source	Degrees Kelvin
1 Candle	1900
2 Carbon filament lamp	2100
3 Gas-filled lamp, 40 watt	2700
4 60 watt	2800
5 100 watt	2870
6 1000 watt	3020
7 Ribbon filament lamp, 108 w	2950
8 CIE ¹ source A	2854
9 Fluorescent "Warm White"	3000
10 Photoflood	3400
11 Carbon (solid) arc	3750
12 Fluorescent "Cool White"	4500
13 Average noon sunlight	5000
14 CIE ¹ source B	4870
15 Carbon (sunshine) arc	6260
16 Fluorescent "Daylight"	6500
17 Overcast sky	6500
18 CIE ¹ source C	6740
19 Light overcast sky	7500
20 Hazy blue sky	9000
21 Clear blue sky	25000

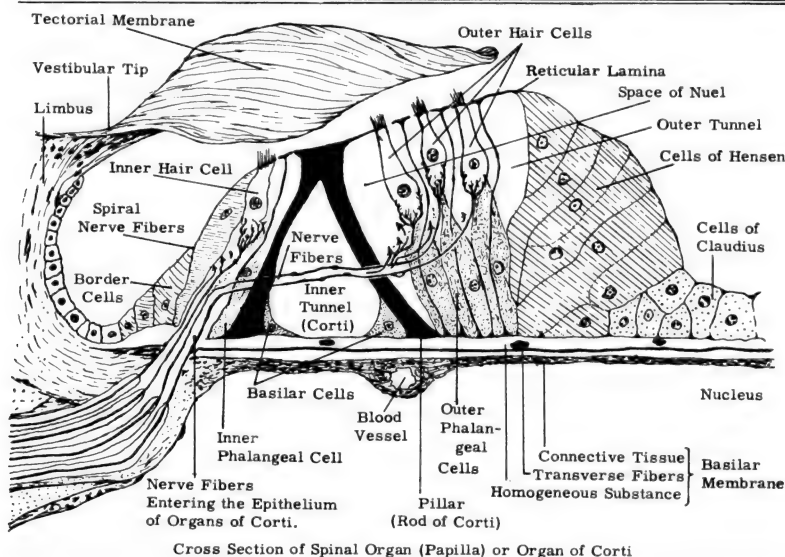
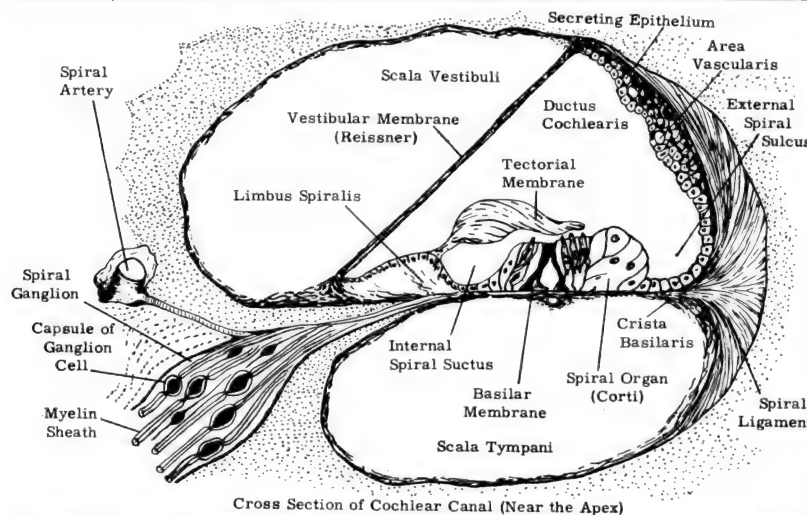
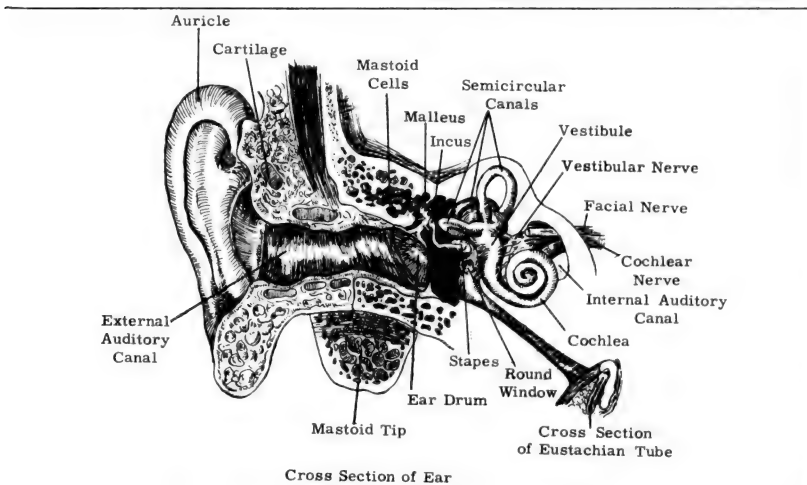
/1/ Foot-lamberts.

/1/ Commission Internationale de l'Eclairage. Source A is characteristic of tungsten light, source B of sunlight and source C of daylight. For details see Hardy, A. C., "Handbook of Colorimetry," Cambridge, Mass.: Technology Press, 1939.

Part XVI: GLOSSARY

APHAKIC. Destitute of the lens of the eye.
 APOSTILB. 9×10^{-2} mL (see also LAMBERT).
 CANDLE (C). Unit of luminous intensity defined by reference platinum standard.
 CANDLEPOWER. Luminous intensity (I) expressed in candles. $I = dF/d\omega$, where F is luminous flux and ω is solid angle in steradians (see LUMEN).
 DECIBEL. A logarithmic measure of the ratio between two quantities. The number of decibels denoting the ratio is 10 times the logarithm to the base 10 of the ratio.
 DIOPTR. Refractive power of a lens (reciprocal of focal length, expressed in meters).
 ERG. Energy of 1 dyne through 1 cm.
 FLUX. Time rate of flow of light.
 FOOT-CANDLE (see FOOT-LAMBERT). Unit of illumination (lumen/sq ft).
 FOOT-LAMBERT (ft-L). 1 ft-L = $1/\pi$ candles/sq ft, and is the same as the apparent foot-candle, and numerically equal to the equivalent foot-candle.
 ILLUMINATION (E). The density of luminous flux on a surface. $E = dF/dA$, where A is area.
 INTENSITY (I). Light-giving power of a source of light (see CANDLEPOWER).
 LAMBERT (L). Unit of luminance equal to $1/\pi$ candles/sq cm. It is equal to the uniform luminance of a perfectly diffusing surface emitting or reflecting 1 lumen/sq cm.
 1 Apostilb (Blondel) = 9×10^{-2} mL.
 LUMEN (lm). Unit of luminous flux; it is equal to the flux through a unit solid angle (steradian) from a uniform point source of one candle.
 LUMINANCE (B). Photometric brightness. It is the luminous intensity (I) of any surface in a given direction per unit of projected area of the surface as viewed from that direction.
 $B = dI/(dA \cos \theta)$, where A = surface area, and θ = angle between direction of observation and 90° line to the surface.
 MESOPIC. Pertaining to vision intermediate between photopic and scotopic (q.v.).
 PHOTON (TROLAND). Retinal illumination for 1 sq mm of pupil area from a luminance of 1 c/sq m.
 PHOTOPIC. Pertaining to vision in bright light.
 SCOTOPIC. Pertaining to vision in dim light.
 STILB. Unit of luminance equal to 1 C/sq m.
 TROLAND (see PHOTON).
 VISUAL ACUITY (V.A.). Reciprocal of angle (1' arc) between 2 black bars just visibly separate.
 λ = Wave length.

Part I: MORPHOLOGY OF THE EAR: MAN



The external auditory canal extends inward (medially) to the tympanic- or drum-membrane. Medial to this, embedded in the bone, lies the irregular air chamber, the middle ear, and medial to the latter is the fluid-filled inner ear or labyrinth. The tympanic membrane is set in the lateral (external) wall of the middle ear, opposite the oval and round windows in the medial wall. Positioned across the chamber from the tympanic membrane to the oval window are the three ossicles (malleus, incus, and stapes), to which are attached the tensor tympanic and stapedial muscles. The handle of the malleus is attached to the drum. The incus is joined at its outer end to the head of the malleus by a flexible joint, and the stapes in turn articulates with the incus. The footplate of the stapes fits into the oval window and is joined to the bony window around its edge by an elastic ligament. The round window is an opening in the bony labyrinth closed by a membrane. The ear receives sound waves on the drum; the vibrations are conducted by the ossicles and are transmitted through the oval window to the fluid and sensory elements in the inner ear (ultimately to the round window). The inner ear consists of the osseous labyrinth, a complicated group of communicating cavities in the bone (the vestibule adjoining the middle ear, the cochlea, and the semicircular canals) and the membranous labyrinth contained in and coextensive with the osseous labyrinth. The membranous labyrinth consists of the semicircular canal, utricle, saccule, and membranous cochlea (ductus cochlearis, scala media). A clear fluid, the perilymph, surrounds the membranous labyrinth; within the membranous labyrinth is the endolymph. (The semicircular canals, utricle, and saccule are involved in equilibrium and are not considered here.) The bony cochlea, a short cone resembling a snail shell, has in it the sense organ for sound perception (organ of Corti, papilla basilaris). Its bony spiral tube is divided by the spiral (bony) lamina, an incomplete partition which is completed by the ductus cochlearis, thus making three tubes, the scala vestibuli, the scala media (ductus cochlearis) and the scala tympani. The scala media has the following structures: Reissner's membrane separating it from the scala vestibule, the stria vascularis (secretory organ), the tectorial membrane resting on the organ of Corti (papilla basilaris), the organ of Corti consisting of supporting cells, pillar cells (tunnel of Corti) and external and internal hair cells (neuro-sensory elements). These structures rest on the basilar membrane which separates it from the scala tympani. The cochlear division of the 8th nerve enters the modiolus of the cochlea to form the spiral ganglion. The dendrites of the ganglion cells are distributed to the spiral organ of Corti, supported by the basilar membrane. The axons of the ganglion cells go to the medulla.

291. THE AUDITORY MECHANISM: MORPHOLOGY AND PHYSIOLOGY (Continued)

Part II: COMPARATIVE MORPHOLOGY OF AUDITORY MECHANISMS

Species		Outer Ear			Tympanic Membrane			Middle Ear							
		External Canal						Cavity	Malleus		Incus	Weight mg.	Stapes		
		Opening Area sq cm	Length cm	Volume ml	Diameter mm	Area sq mm	Thick-ness mm		Volume ml	Weight mg			Length Total mm	Weight mg	Length mm	Width mm	Area sq mm
1	Man	0.3-0.5	2.3-3.0	1.04	8-10	56-85	0.1	2	23-27	7.6-9.1	25-32	2.0-4.3	2.6-3.7	2.6-3.7	
2	Cat				5.5-8.6	32-48	0.03		10-11.4		3-4.5	0.2-0.9	1.6	1.1-1.7	1.1-1.3
3	Dog														
4	Guinea pig					23-28									0.8-0.9

1	Man	0.3-0.5	2.3-3.0	1.04	8-10	56-85	0.1	2	23-27	7.6-9.1	25-32	2.0-4.3	2.6-3.4	1.1-1.7	2.6-3.7
2	Cat				5.5-8.6	32-48	0.03		10-11.4		3-4.5	0.2-0.9	1.6	1	1.1-1.3
3	Dog														
4	Guinea pig					23-28									0.8-0.9

Species	Middle Ear (concluded)				Inner Ear													
	Muscles				Oval Window Area sq mm	Round Window Area sq mm	Turns no.	Volume cu mm	Cochlea									
	Tensor Tympani		Stapedius						Scala Vestibuli		Scala Tympani		Scala Media					
	Cross Section sq mm	Length mm	Cross Section sq mm	Length mm					Volume cu mm	Max. Diam. mm	Volume cu mm	Area Helico-trema ¹ sq mm	Volume cu mm	Length mm				

1	Man	4.8-6.9	23-26	4.9	6.3	2.0-3.7	2	2.2-2.9	98	54	3.5	37	0.08-0.2	6.7	35
2	Cat					1.1-1.3	2	3+			2.7				25
3	Dog						3+	3.2			3.0				16-17
4	Guinea pig					1.4	1.0	4							18.8

1/ Communicating part between scala tympani and scala vestibuli. 2/ From base to apex. 3/ Measurement made at midpoint of the length of the basilar membrane. 4/ The tympanic layer. 5/ The maximum is for a point near the apex of the cochlea; at the extreme apex the area diminishes to 0.015 sq mm.

Part III: COMPARATIVE AUDITORY SYSTEMS

Species	Organ Type	Location	Accessory Structures
Vertebrates			
1 Man	Organ of Corti. Pillars, tunnel, outer and inner hair cells, Hensen's cells, Claudius' cells, tentorium, Reissner's membrane.	Cochlea, 2½ to 3 turns.	Mastoid tip well developed. Mastoid area more or less pneumatic in adult. Apex pneumatic, semipneumatic, or containing either fatty or hemopoietic marrow. Stapes with posterior crus bowed. Arachnoid tissue fills aqueduct.
2 Bat	Organ of Corti, with tall pillars and stiff rod spiralling in basilar membrane in floor of tunnel.	Cochlea, 2 turns. Fibers of VIIIth cochlear branch pass straight up modiolus to apical ganglion cells. Some species spiral.	Middle ear muscles large, especially tensor tympani, with heavy nerve supply. Stapediovestibular ligament composed of discrete fiber cells. Cartilaginous trap door for closing external ear. Drum membrane very thin. Stapedius muscle unseparated by bone from jaw muscles, i.e., no bony enclosure posteriorly for middle ear. No bulla, mastoid or pneumatization. Large supply of fat in bones and among head muscles. Stapedial artery present in some species.
3 Cat and dog	Organ of Corti; no unique characteristics described.	Cochlea, 3 turns.	Bulla divided into 2 compartments separating oval and round windows. Middle ear muscles relatively large. Superior sinus of Eustachian tube widely patent. Wide cochlear aqueduct.
4 Guinea pig	Well-developed organ of Corti. High or tall Hensen's cells.	Cochlea, 4½ turns. Spiral ganglion follows through modiolus to apex.	Persistent stapedial artery and bony bar. Middle ear completely enclosed by bulla. Coils of cochlea exposed in molded form on medial wall of middle ear. Wide cochlear aqueduct.
5 Monkey	Spiral organ of Corti.	Cochlea, 2½ turns.	Middle ear, mastoid, and petrous apex completely enclosed in bone. No mastoid tip developed. Pneumatization extreme in both mastoid and apex. Bony Eustachian tube difficult to identify because of pneumatization of apex. Internal carotid artery courses through apex. No stapedial artery. Long bony external auditory canal. Cochlear aqueduct narrow.
6 Opossum	Spiral organ of Corti rests on basilar membrane.	Cochlea, 2 turns. Ganglion follows through modiolus to top coil, but is untwisted.	Incipient bulla. Membrana tympani on half-shell of bone. No bony external auditory canal. Ossicles small and fragile. Styloid process participates in articulation near head of stapes. Stapedius muscle large (derived from depressor mandibulae), occupying whole posterior wall of middle ear. Tensor tympani small (derived from pterygoid). Malleus fan-shaped anterior process. VIIIth nerve passes uncovered by bone through middle ear and emerges at level of round window. Cochlear aqueduct is Y-shaped, one limb entering scala tympani and one directed toward middle ear. Large IXth ganglion in floor of middle ear.

291. THE AUDITORY MECHANISM: MORPHOLOGY AND PHYSIOLOGY (Continued)

Part III: COMPARATIVE AUDITORY SYSTEMS (Concluded)

Species	Organ Type	Location	Accessory Structures
Vertebrates (continued)			
7 Platypus ¹	Organ of Corti. Lagena sense organ.	Lagena. Incipient cochlea.	Recessus scala tympani narrows into funnel-shaped tube to form cochlear aqueduct.
8 Birds	Sensory cells bathed in fluid. Papilla basilaris.	Papilla lagena, basilaris and, neglecta. Papilla lagena elongated. Developed tegmentum vasculosum. Sacculle reduced. No crus commune. Superior semicircular canal large and encircling others. Posterior canal smallest and communicating perilymph with horizontal.	Membrana tympani, columella, Eustachian tube, oval and round windows. Round window separates perilymph and intracranial arachnoid spaces from middle ear. Single columella. First appearance of external ear. ²
9 Turtle		Papilla lagena, basilaris, and neglecta. Shows mound of Corti.	Membrana tympani, columella of two articulating pieces, Eustachian tube, oval and round windows. Latter separates perilymph and arachnoid spaces from middle ear.
10 Frog		End-organs as in fish.	Membrana tympani, columella, Eustachian tube, oval and round windows. Latter separates perilymph and intracranial arachnoid spaces from middle ear.
11 Toad ³	Also, probably some sensation through skin of foot pads.		Vestibulo-scapular conduction through forefeet. Vestibulo-squamosal conduction direct from ground.
12 Fish	Sensory hair cells bathed in fluid. Lagena sacculle.	Lateral line organs for slow vibrations. Labyrinth in head, bilateral, developed from lateral line organs. Cristae of 3 semicircular canals in 3 planes of space. Macula of utricle. Lagena and macula of very large sacculle. Large otoliths. Papilla neglecta present in most fishes.	Forerunner of middle ear in carp, goldfish, catfish, etc. Weberian ossicles. Oval window.
Invertebrates			
13 Cricket	Membrani tympani. Sensory cells of graded sizes.	Front leg below knee. May be second one in 2nd abdominal section.	
14 Grasshopper ⁴	Membrani tympani connected with leg tracheal vesicles. Sensory cells of graded sizes.	Front segment of abdomen.	
15 Grasshopper ⁵	Membrani tympani with external ear and ear slit. Sensory cells of graded sizes.	Tibia of foreleg.	

/1/ Duckbill. /2/ External ear of rooster can be closed when crowing. /3/ Tree toad; also salamander. /4/ Short antennae. /5/ Long antennae, Katydid.

Part IV: FUNCTIONS OF AUDITORY COMPONENTS: VERTEBRATES

Species	Segment	Component	Function
1 Man ¹ , all mammals	External ear	Auricle.	Collects sound waves. Protects ear mechanism.
		External ear canal.	Passageway for sound waves.
	Middle ear	Ear drum (tympanic membrane).	Picks up sound waves and starts rocking of ossicles.
		Ossicles: malleus, incus, stapes.	Rocking motion transmits sound waves to perilymph and membranous cochlea through oval window.
		Eustachian tube.	Carries air from nasopharynx to middle ear.
		Antrum, mastoid cells.	Lightens skull; helps maintain air on medial side of drum.
	Internal ear	Osseous labyrinth: vestibule; horizontal semicircular canal; anterior and posterior vertical semicircular canals. Bony cochlea.	Protects membranous labyrinth.
		Membranous labyrinth: utricle, semicircular canals attached; sacculle, cochlea attached; 3 semicircular canals.	Static equilibrium. Orientation in space.
		Cochlea: basilar membrane, organ of Corti.	Equilibrium, in motion (canals).
			Organ of hearing.
2 Birds and reptiles ²	External ear	Auditory meatus.	
	Middle ear	Tympanic membrane, columella ³ .	Transmits sound.
	Internal ear	Utricle, lagena sacculle, papilla basilaris.	Dual function of equilibrium and hearing.
3 Amphibians	No external ear		
	Middle ear	Tympanic membrane, columella ⁴ .	Transmits sound.
	Internal ear	3 semicircular canals. Vestibule: utricle, lagena sacculle, papilla basilaris.	Dual function of equilibrium and primitive auditory organ.
4 Fishes	No external ear		
	No middle ear		
	Internal ear	3 semicircular canals ⁵ . Vestibule: utricle, lagena sacculle.	Dual function of equilibrium and primitive auditory organ.

/1/ Cochlea highly developed. In all except aquatic mammals, middle ear has three ossicles. External ear present. /2/ Bird organs are similar in structure to those of reptiles, including basilar membrane. Tympanic organs also have hairs beneath the tympanum. /3/ Two bones, inner one acts as stapes. No middle ear in snakes. /4/ Bony rod, action similar to stapes. /5/ Higher fishes have three canals, hagfish one, and lamprey two.

Part V: HEARING THRESHOLDS FOR PURE TONES: MAMMALS

The least "strength" of a given stimulus that can just elicit a response from an organism or its parts is the threshold for the type of stimulation employed. For the sense of hearing, the "strength" (intensity) of a sound stimulus is expressed in terms of the rate of flow of sound energy at the hearing point. For binaural hearing, this is the midpoint of the position of the listener's head when the head is placed in the sound field. The unit of power (rate of energy flow) is commonly watts/sq cm. Measurements of hearing are often made, however, in terms of sound-wave pressure (dynes/sq cm) in the air at the hearing point. As the rate of energy flow is proportional to the square of the sound pressure, both are convertible to the decibel (db) scale. The least sound pressure (dynes/sq cm) at which a tone having a frequency of 1000 cycles/sec (cps) can be heard by a human observer is approximately 0.0002 dynes/sq cm. This value is used as a basis for comparison of sound intensity levels, serving as the zero reference level for a logarithmic intensity scale. The unit of this scale is the db. The intensity level of sound, in db, is $10 \times \log_{10}$ of the ratio of the intensity of this sound to the reference intensity. As the intensity is also proportional to the square of the sound pressure, the level of a sound in db can be calculated from sound pressure in dynes/sq cm by the formula $db = 20 \log p_1/p_2$, where p_1 is the pressure of a sound of a given frequency, and p_2 is 0.0002 dynes/sq cm (the threshold pressure of a 1000 cps tone). Negative values for decibels indicate that less energy is required to make the sound audible than is required for a tone of 1000 cps.

Sound Wave Frequency ¹ cps	Man ² db	Cat db	Chimpanzee db	Dog db	Guinea Pig db	Monkey db	Rat db
1 64	46						
2 100	37	38		34	60	45	
3 128	30		20		41	20	
4 200	23	24		21			
5 256	16		8		26	10	
6 400	10	9		9			
7 500	6	6		8		7	
8 512	5		-3		11		65
9 1,000	0	-1		1		-3	
10 1,024	0		-10		2		41
11 2,000	-4	-2		-3		-5	
12 2,048	-5		-14		18		40
13 2,896	-7						31
14 3,000	-8	-7		-7			
15 4,000	-8	-6		-6		3	
16 4,096	-7		-6		14		30
17 5,000	-4	-8		-10			
18 5,792	1						30
19 8,000	7	-7		-3		-14	
20 8,192	8		-9		34		-14
21 10,000	9	-7		-6			
22 11,584	10						0
23 14,000	13	-9		-5			
24 16,000	20	-4		2			

/1/ Each frequency corresponds to a different pure tone. /2/ The sound is generated at intensity just sufficient to be heard binaurally, the experimental subject is then removed, and the intensity at the hearing point is measured.

Part VI: RANGE OF HEARING: ANIMALS

Unless otherwise indicated, values are based upon changed behavior of the intact animal in response to tonal stimuli. The data, however, are inhomogeneous, and the values are not strictly comparable with one another because of different criteria used in determining the lower and upper limits. The limits are not actually single numbers as they depend both on the intensity of the stimulus and the endpoint chosen to define "hearing."

Species	Frequency Limit	
	Lower	Upper
	cps	
1 Man	15 ¹	20,000 ¹
2 Bat	30 ²	98,000 ²
3 Cat	30 ²	45,000 ³
4 Chimpanzee		33,300
5 Dog		40,000
6 Dolphin, Tursiops	100	130,000 ⁴
7 Guinea pig		40,000
8 Monkey		33,600
9 Mouse, deer	500	95,000
10 Mouse, harvest		17,500
11 Opossum	100	19,000 ³
12 Rat		40,000
13 Pigeon	100	12,000
14 Alligator		340
15 Turtle		1,200
16 Axolotl		240
17 Frog	50	10,000
18 Catfish		13,000
19 Characinidae		10,000
20 Goldfish		2,700 ⁴
21 Minnow		7,000
22 Cricket (Acridium aegyptium)		20,000
23 Cricket (Gryllus assimilis)	300	8,000
24 Grasshopper (Arphia sulfurea)	300	20,000
25 Katydid (Pterophylla camellifolia)	430	45,000 ²

/1/ At the lower end the sense of hearing merges into the sense of feeling and vibration. On the musical scale (equal tempered chromatic), the note low C (C_0) has a frequency of 16, middle C (C_4 , four octaves higher) 256, middle A (American Standard Pitch) 440, and high C (C_5) 4186. /2/ By recording electrical potentials from the region of the sensory organ; does not necessarily represent the capacities of the entire auditory system. /3/ Electrical responses of the cochlea up to 30,000 cps have been reported. /4/ At least as high as this figure.

Part VIII: PURE TONES OF EQUAL LOUDNESS: MAN

The greater the intensity of a pure tone, the greater is its loudness up to the level of discomfort or pain. However, the loudness of a sound is a subjective estimate, whereas its intensity is measured objectively. In general, two tones of equal intensity but different frequency are not necessarily equally loud to the hearer. Each successive column, 10-120, contains values that are equal in loudness in the same column, but louder than values in the preceding column. The intensity levels for 1000 cps (Line 9) have been used as a scale of reference and appear at the head of each column.

Pure Tone		10	20	30	40	50	60	70	80	90	100	110	120	Threshold of Feeling	
	cps	db	db	db	db	db	db	db	db	db	db	db	db	db	cps
1	Thirty	5	9	12	15	17	20	22	25	29	36	46	64	82	35
2	Fifty	5	11	15	18	22	25	29	32	38	46	57	72	92	
3	Seventy	6	12	16	21	25	28	33	37	44	53	65	80	94	75
4	One hundred	7	14	19	24	28	33	38	44	51	62	72	85	101	
5	Two hundred	8	16	23	29	37	44	51	58	67	77	87	100	109	
6	Three hundred	8	17	25	32	40	48	57	66	75	85	95	107	116	400
7	Five hundred	10	19	28	36	45	54	65	74	84	95	105	115		
8	Seven hundred	11	20	30	39	48	59	69	79	89	99	110	120	130	800
9	One thousand	10	20	30	40	50	60	70	80	90	100	110	120		
10	Two thousand	10	21	32	43	53	64	74	83	92	100	110	118	132	1500
11	Three thousand	10	21	32	43	54	65	74	83	91	100	109	118	133	3100
12	Five thousand	11	23	34	44	55	65	74	82	90	99	106	115		
13	Seven thousand	10	21	32	44	56	65	74	83	90	98	105	112	125	6500
14	Ten thousand	10	21	32	43	55	64	74	82	90	96	104	111		

292. CHEMORECEPTION THRESHOLDS: CHORDATES

Animal	End Organ or Region of Body	Substance	Medium ¹	Method ²	Mean or Median Threshold
1 Tongue worm 2 (Balanglossus sp)	General integument	HCl	SW	W	0.002N
3		NaOH or KOH	SW	W	0.0025N
4		KCl	SW	W	0.005N
5		Quinine	SW	W	0.001M
6 Tunicate 7 (Ascidia atra)	Oral siphon	HCl	SW	W	0.0016N
8		Formic acid	SW	W	0.0018N
9		NaOH or acetic acid	SW	W	0.010N
10		NH ₄ OH	SW	W	0.015N
11		KSCN	SW	W	0.10N
12		K acetate	SW	W	0.15N
13		KCl	SW	W	0.20N
14		NH ₄ Cl	SW	W	0.30N
15		NaCl	SW	W	0.40N
16		Strychnine	SW	W	0.00005M
17		Morphine ³	SW	W	0.001M
18		Quinine	SW	W	0.004M
19		Ethyl ether ⁴	SW	W	0.02M
20		Ethyl alcohol	SW	W	0.75M
21 Lancelet 22 (Amphioxus)	Mouth	HCl	SW	W	0.002N
23	Mid-trunk	HCl	SW	W	0.10N
24	Tail	HCl	SW	W	0.01N
25 Lamprey 26 (Petromyzon sp) 27 ammocoetes larvae	Mouth	HCl	SW	W	0.008N
28		NaOH	SW	W	0.001N
29		NaCl	SW	W	0.025N
30		Quinine	SW	W	0.0016M
31	Mid-trunk	NaOH	SW	W	0.01N
32		HCl or NaCl	SW	W	0.05N
33		Quinine	SW	W	0.10M
34	Tail	NaOH	SW	W	0.002N
35		HCl	SW	W	0.025N
36		NaCl	SW	W	1.0N
37		Quinine	SW	W	0.05M
38 Dogfish, smooth 39 (Mustelus sp)	Mouth	NaOH	SW	W	0.01N
40		HCl	SW	W	0.013N
41	Mid-trunk	HCl	SW	W	0.02N
42		NaOH ⁵	SW	W	0.05N
43	Tail	HCl	SW	W	0.025N
44 Catfish 45 (Aniurus sp)	Mouth	NaOH	SW	W	0.01N
46		NaCl	SW	W	0.02N
47		HCl	SW	W	0.05N
48		Quinine	SW	W	0.007M
49	Mid-trunk	HCl	SW	W	0.02N
50		NaOH ⁵	SW	W	0.05N
51	Tail	HCl	SW	W	0.025N
52 Rat 53 (Rattus rattus 54 norvegicus, and 55 var. albinus)	Tongue (taste buds)	NaCl	FW	E	0.0081% (0.0075-0.0095%)
56		NaCl	FW	A	0.06%
57		HgCl ₂	FW	R	0.004% (0.001-0.007%)
58		As ₂ O ₃	FW	R	0.0065% (0.002-0.02%)
59		Glucose	FW	A	0.20% (0.1-0.4%)
60		Galactose	FW	A	1.6% (0.5-2.8%)
61		Lactose	FW	R	4.8% (2.8-6.5%)
62		Maltose	FW	A	0.06% (0.04-0.08%)
63		Sucrose	FW	A	0.57% (0.1-0.8%)
64		Quinine HCl	FW	A	0.00005% (0.000012-0.0002%)
65		Quinine HCl	FW	R	0.0003% (0.0001-0.0012%)
66		Quinine SO ₄	FW	R	0.00072% (0.00038-0.0016%)
67		Phenylthiocarbamide	FW	R	0.0003% (0.00005-0.02%)
68		α-Naphthylthiourea	FW	R	0.001% (0.0005-0.002%)
69		Phenylthiourea	FW	R	0.002% (0.0001-0.008%)
70		Thiosemicarbazide	FW	R	0.0023% (0.0005-0.005%)
71		Strychnine SO ₄	FW	R	0.008% (0.005-0.02%)
72	Adrenalectomized	NaCl	FW	E	0.0104% (0.0048-0.017%)
73 Rabbit, European 74 (Oryctolagus cuniculus)	Tongue (taste buds)	HNO ₃	FW	R	0.085N
75		HCl	FW	R	0.12N
76		H ₂ SO ₄	FW	R	0.14N
77		Acetic acid	FW	R	0.17N
78		NaI	FW	R	0.79N
79		NaNO ₃	FW	R	0.81N
80		NH ₄ Cl	FW	R	1.0N
81		KCl	FW	R	1.1N
		Na acetate or NaSO ₄	FW	R	1.3N
		NaCl or CaCl ₂	FW	R	1.4N
		LiCl	FW	R	1.8N
		Sucrose	FW	A	0.031M
82 Cat, domestic 83 (Felis catus)	Tongue (taste buds)	HCl	FW	E	0.02N(0.007-0.07N)
84		NaCl	FW	E	0.1-0.3N
85		Quinine	FW	E	0.001-0.005M
86 Monkey 87 (Macaca mulatta)	Tongue (taste buds)	Quinine HCl	FW	A	0.0031%(0.0003-0.006%)
88		Quinine HCl	FW	R	0.025% (0.0015-0.05%)
89 Chimpanzee 90 (Pan troglodytes)	Tongue (taste buds)	Quinine HCl	FW	A	0.0003%
91		Quinine HCl	FW	R	0.0062%

/1/ Dispersion medium for the stimulating substance. SW=sea water; FW=fresh water. /2/ Experimental procedure used to indicate reception. W=generalized avoidance reaction or withdrawal of part of body; E=electro-physiological methods; A=acceptance thresholds for materials offered in food or water; R=rejection thresholds. /3/ Same value for amyl alcohol. /4/ Same value for chloral hydrate. /5/ Same value for tail, NaOH.

293. TASTE AND OLFACTION THRESHOLDS: MAN

Values derived from early literature were excluded from this table. It is considered that publication of the older values might perpetuate certain ambiguities, if not errors, that have arisen in translation and recalculation. Data presented below have been selected from the more recent research publications.

Part I: TASTE THRESHOLDS

Values are lowest molar concentrations that can be distinguished as different from water alone.

Substance	Threshold Mole/L	Substance	Threshold Mole/L
1 Formic acid	0.0018	13 n-Pentanol	0.016
2 Acetic acid	0.0028	14 n-Hexanol	0.002
3 Butyric acid	0.0035	15 n-Heptanol	0.0013
4 Valeric acid	0.0037	16 n-Octanol	0.0006
5 Tartaric acid	0.0011	17 1,2-Butanediol	0.052
6 Glutaric acid	0.00225	18 1,3-Butanediol	0.016
7 Succinic acid	0.0016	19 1,4-Butanediol	0.031
8 Lactic acid	0.0028	20 1,5-Pentanediol	0.017
9 Oxalic acid	0.0010	21 1,6-Hexanediol	0.013
10 Ethanol	0.32	22 1,8-Octanediol	0.016
11 n-Propanol	0.11	23 Ethylene glycol	0.063
12 n-Butanol	0.028	24 Trimethylene	0.037

Part II: THRESHOLDS OF TASTERS vs NON-TASTERS

Tasters are individuals relatively sensitive to phenylthiourea; non-tasters are relatively insensitive. Values are lowest molar concentrations that can be distinguished as different from water alone.

Substance	Tasters Mole/L	Non-Tasters Mole/L
1 Urea	0.132	0.132
2 Phenylurea	0.00551	0.00551
3 Thiourea	0.00295	0.0553
4 Phenylthiourea	0.000020	0.00306
5 Diphenylthiourea	0.000013	0.000070
6 Acetylthiourea	0.000093	0.00719
7 Diacetylthiourea	0.000106	0.002068
8 Thioglyoxaline	0.000155	0.00845
9 Thio-methylhydantoin	0.000508	0.00217
10 Uracil	0.011	0.008928
11 Methyl-thiouracil	0.000296	0.001204

Part III: OLFACTION THRESHOLDS

P_{olf} = partial pressure of substance for olfactory recognition; P^0 = vapor pressure of pure substance; $A_{olf} = P_{olf} / P^0$ = the fraction of saturated vapor of substance that allows threshold recognition.

Substance	Concentration mg/L	P_{olf} atm x 10 ⁻⁷	P^0 atm (37°C)	A_{olf} x 10 ⁻³
1 Amyl acetate	0.039	90	0.013	1
2 Ethyl acetate	0.69	1760	0.23	1
3 Butyric acid	0.009	18	0.003	1
4 Ethyl ether	5.83	13,000	1.1	1
5 Chloroform	3.30	6700	0.4	2
6 Artificial musk	0.00004	0.029	0.0000013	2
7 Carbon tetrachloride	4.53	6700	0.24	3
8 Valeric acid	0.029	50	0.001	5
9 Amyl alcohol	0.225	500	0.007	7
10 Nitrobenzene	0.146	300	0.0007	40
11 Methyl salicylate	0.10	150	0.00026	60

Substance	Threshold A_{olf} x 10 ⁻⁴
1 Methyl alcohol	500
2 Ethyl alcohol	300
3 n-Butyl alcohol	7
4 n-Hexyl alcohol	7
5 n-Octyl alcohol	30
6 n-Decyl alcohol	200
7 n-Dodecyl alcohol	1000
8 Ethane	170
9 n-Butane	8
10 n-Pentane	10
11 n-Heptane	50
12 n-Nonane	200
13 n-Undecane	450
14 n-Butyl chloride	5
15 n-Heptyl chloride	30
16 n-Decyl chloride	100

294. PAIN SENSITIVITY: MAN

Specific thresholds of pain are necessarily arbitrary, since the variations between individuals, and within an individual under differing conditions and accommodations, are great. Widely accepted standards for measurement have not yet been achieved. Body locus of stimuli materially affects mechanical and electrical thresholds, and chemical pain stimulation is generally in proportion to the pH extreme. An accepted thermal pain threshold of 0.21 gram-calories/sec/sq cm reported (Woodson, W. E., Human Engineering Guide, 1954). The data in this table, from the research of J. D. Hardy, H. G. Wolff, and H. Goodell, are based on only limited samplings of subjects and should under no circumstances be considered standards.

Part I: PRICKING PAIN THRESHOLDS

Values are for a final skin temperature of 34°C, corrected from observed threshold values by the formula: $Q_{34} = Q + 20(T_s - 34)$, where Q_{34} = pain threshold for 34°C; Q = observed pain threshold in millicalories per second x square centimeter; and T_s = final skin temperature. Values in parentheses are estimate "b" of the 95% range (cf Introduction).

Skin Area ¹	Final Skin Temp. °C	Pain Threshold millical. ² /sec/sq cm	Skin Area ¹	Final Skin Temp. °C	Pain Threshold millical. ² /sec/sq cm
1 Forehead	45.7	235(181-289)	19 Arch	44.3	200(144-256)
2 Cheek (zygoma)	44.6	210(156-264)	20 Heel	53.7	390(202-478)
3 Nose	44.8	215(151-279)	21 Heel, corneal layer shaved off		250
4 Lips	44.1	200(124-276)	22 Shoulder	44.8	215(143-287)
5 Chin	45.0	220(166-274)	23 Neck (nape)	43.8	195(147-286)
6 Chest	44.8	215(127-303)	24 Back (upper)	43.5	185(121-249)
7 Nipple	43.8	200(136-264)	25 Back (middle)	43.8	195(147-242)
8 Abdomen	43.9	200(164-236)	26 Back (lower)	42.2	160(104-216)
9 Groin	43.3	185(137-233)	27 Buttock	42.4	165(89-241)
10 Thigh (posterior)	42.8	175(119-231)	28 Arm (upper)	43.4	185(117-253)
11 Thigh (anterior)	42.6	170(114-226)	29 Forearm (volar)	44.4	210(146-274)
12 Kneecap	42.7	175(139-211)	30 Forearm (outer)	44.0	200(152-248)
13 Popliteal space	43.5	190(150-230)	31 Hand (back)	43.8	195(131-259)
14 Calf	43.0	185(129-241)	32 Finger pad	47.1	260(180-340)
15 Shin	43.9	190(146-234)	33 Fingernail		215(185-245)
16 Ankle	44.0	190(146-234)	34 Palm, center	45.1	220(152-288)
17 Foot, dorsum	43.2	180(124-236)	35 Palm, over callus	45.6	230(158-312)
18 Toes, dorsum	43.4	185(117-253)			

/1/ Ink-blackened skin areas exposed to radiant heat stimulus for three seconds. /2/ Millicalories = small calories/1000.

Part II: SCALE OF PRICKING PAIN INTENSITY

It is not usually possible to discriminate between stimuli less than two steps apart; therefore, for purposes of this table, the unit of pain sensation is equivalent to two steps and is designated as a dol. Ceiling pain intensity has a value of 10½ dols, as there are 21 steps between pain threshold and ceiling pain, under conditions specified.

Stimulus Intensity ¹ millicalories ² /second/sq cm	Increments of Intensity Discrimination	No. of dols	Stimulus Intensity ¹ millicalories ² /second/sq cm	Increments of Intensity Discrimination	No. of dols
1 220	Pain threshold		12 300	10	11th
2 227	7	1st	13 310	10	12th 6
3 234	7	2nd	14 320	10	13th
4 241	7	3rd	15 335	15	14th 7
5 248	7	4th	16 350	15	15th
6 255	7	5th	17 365	15	16th 8
7 262	7	6th	18 380	15	17th
8 269	7	7th	19 395	15	18th 9
9 276	7	8th	20 425	30	19th
10 283	7	9th	21 480	55	20th 10
11 290	7	10th	22 680	Pain ceiling	

/1/ Stimulus is intense radiant heat applied for three seconds to ink-blackened skin of forehead or forearm. /2/ Millicalories = small calories/1000.

Part III: PRESSURE PAIN THRESHOLDS

Surface	Threshold ¹ g/sq mm
1 Cornea	0.2
2 Conjunctiva	2
3 Abdomen	15
4 Forearm, front	20
5 Forearm, back	30
6 Calf	30
7 Back of hand	100
8 Sole of foot	200
9 Finger tip	300

/1/ Pressure applied with sharp needle.

295. BIOLUMINESCENCE

Table adapted from data presented in E. Newton Harvey's "Bioluminescence," Academic Press, 1952.

Groups and Typical Luminous Genera	Habitat ¹	Type of Light ²	Knowledge of Histology ³	Necessity for Oxygen ⁴	Luciferin-Luciferase Reaction ⁵	Adenosine Triphosphate Reaction ⁶	Inhibition by Light ⁷	Color of Fluorescence ⁸	Color of Bioluminescence ⁹
1 Bacteria (Photobacterium, Achromobacter, Vibrio)	M, F ¹⁰	I	±	+	+	-	±	-	Bluish to greenish (470, 490, 495)
2 Fungi basidiomycetes (Panus, Omphalia, Pleurotus, Polyporus, etc.)	T	I	±	+	-	-	-	-	White (528, 520)
3 Radiolaria (Thalassiosira, Sphaerocozum, Collozum, Myxosphaera, Collosphaera)	M	I	±	-	-	-	-	-	Faint bluish
4 Dinoflagellata (Noctiluca, Ceratium, Gonyaulax, Gymnodinium, Pyrocystis, etc.)	M	I	±	+	-	-	±DN	-	White or bluish
5 Porifera (Grantia)	M	I?	-	-	-	-	-	-	Yellowish
6 Hydrozoa (Campanularia, Obelia, Aglaophenia, etc.)	M	I?	-	-	-	-	-	-	Yellowish
7 Hydromedusae (Aequorea, Halisauria, Phialidium, etc.)	M	I?	-	-	-	-	-	-	Bluish green
8 Siphonophora (Diphyes, Hippopodius, Agalma, etc.)	M	I?	-	-	-	-	-	-	Faint bluish
9 Scyphomedusae (Pelagia, etc.)	M	E?	±	-	-	-	± ¹¹	-	Greenish blue
10 Pennatulacea (Cavernularia, Pennatula, Renilla, Pteroeides, etc.)	M	I	±	+	-	± ¹²	± ¹³	-	Yellowish
11 Gorgonacea (Ceratois, Primnois, etc.)	M	?	-	-	-	-	-	-	Pale lilac
12 Ctenophora (Mnemiopsis, Beroë, Pleurobrachia, Bolinopsis, Eucharis, etc.)	M	I	±	-	-	-	+	Greenish	Blue-green
13 Nemertinae (Emplectonema)	M	I	+	+	-	-	-	-	Bluish white
14 Polychaeta (Achiropia, Polynaë, Harmothoe, etc.)	M	I	+	+	-	-	-	Yellowish	Yellowish
15 Alciopidae (Calizonella, Corynocephalus, etc.)	M	-	-	-	-	-	-	-	Bluish
16 Tomopteridae (Tomopteris)	M	I?	±	-	-	-	-	-	Yellowish
17 Syllidae (Odontosyllis, etc.)	M	E	±	+	+	-	-	-	Bluish
18 Eunicidae (Onuphis)	M	I	-	-	-	-	-	-	Bluish green
19 Chaetopteridae (Chaetopterus, Mesochaetopterus, etc.)	M	E	+	+	-	-	-	Bluish	Bluish
20 Cirratulidae (Cirratulus, Heterocirrus, etc.)	M	E	+	+	-	-	-	-	Yellow-green
21 Terebellidae (Thelepus, Polycirrus)	M	E	+	+	-	-	-	-	Bluish
22 Oligochaeta (Microcolex, Eisenia, Pontodrilus, Octochaetus, etc.)	T ¹⁴	E	+	+	- ¹⁵	-	-	Yellow-green	Yellow-green (550)
23 Nudibranchia (Pleurobranchia, Phyllirhoe, Kaloplocamus, etc.)	M	E ¹⁶	+	+	-	-	-	-	Bluish white
24 Pulmonata (Ariophantidae (Dyckia)	T	I	-	-	-	-	-	-	Bluish
25 Latiidae (Latia)	F	E	+	+	+	-	-	-	Bluish green
26 Prosobranchia (Planaxis)	M	I	-	-	-	-	-	-	Bluish
27 Bivalvia (Pholas, Roccellaria)	M	E	+	+	+	-	-	-	Greenish blue
28 Vampyromorpha (Vampyroteuthis)	M	I	+	+	-	-	-	-	Bluish ¹⁸ or yellowish
29 Decapod squid ¹⁷ (Oegopsida (Watasenia, Lycoteuthis, Histiotteuthis, Calliteuthis, Chiroteuthis, Cranchia, etc.)	M	I	+	+	-	-	-	-	Bluish ¹⁹
30 Myopsida (Iniotteuthis, Rondeletia, Sepiella, Spirula, etc.)	M	Bs or Bp	+	+	-	-	-	-	Yellowish blue
31 (Heteroteuthis, Stomatoteuthis) ²⁰	M	E	+	+	-	-	-	-	Blue (480-470)
32 Ostracoda (Cypridina, Pyrocypris, Conchoecia, etc.)	M	E	+	+	+	-	+	Yellow	Greenish ²¹
33 Copepoda (Pleuromma, Leuckartia, Heterochaeta, Oncaea, etc.)	M	E	±	+	-	-	±DN	Greenish ²¹	Greenish
34 Isopoda (Megaliga, Porcellio)	MT	Bp	-	+	-	-	-	-	Bluish
35 Amphipoda (Gammaridea (Talitrus, Orchestia, etc.)	M	Bp	-	+	-	-	-	-	Bluish
36 Hyperidea (Scypholanceola, Streetsia, Parapronoe)	M	I?	±	-	-	-	-	-	Greenish yellow ²²

/1/ F = fresh water; M = marine; T = terrestrial. /2/ Bp = light emission owing to parasitic luminous bacteria; Bs = light emission owing to symbiotic luminous bacteria; E = self-luminosity with extracellular light emission from secreted material; I = self luminosity with intracellular material. /3/ + = cytology of the photogenic cell or histology of the light organ is well known; - = cytology or histology unknown; ± = further study of cytology or histology is desirable. /4/ + = dissolved molecular oxygen is necessary for light production; - = light will appear in complete absence of oxygen (Pt and H₂, or, in excess, hydrosulfite). /5/ + = positive reaction if light appears when a hot water extract of the luminous cells allowed to cool (luciferin) is mixed with a cold water extract of the luminous cells allowed to stand until the light disappears (luciferase); - = a negative reaction. /6/ + = positive reaction if a non-luminous water extract of the luminous tissue containing magnesium emits light when the sodium salt of adenosine triphosphate is added; - = a negative reaction. /7/ + = marked inhibition of luminescence of single-celled organisms or of luminescent extracts by sunlight; - = no marked inhibition; ± = some species show light inhibition, others do not; DN = day-night rhythm of luminescence such that the intact living organism does not luminesce in the daytime even if kept in the dark. /8/ - = no marked fluorescence in near ultraviolet light or after functional activity. /9/ Figures in parentheses are wavelengths of maximum emission where spectrophotometric curves are known. /10/ Some luminous bacteria live on the flesh of terrestrial animals. /11/ Inhibition has been observed. /12/ Adenosine triphosphate reaction positive in Renilla Kollikeri and negative in R. reniformis. /13/ In Renilla, inhibition and no inhibition have been observed. /14/ Pontodrilus matsushimensis lives in sand, wet by the sea. /15/ Thermolabile and thermostable components demonstrated. /16/ Kaloplocamus reported to have intracellular luminescence. /17/ The location of luminous organs has been tabulated by G. Grimpe and H. Hoffman (Tab. Biol. 6:462-4, 1930). /18/ Red, white, and blue in Lycoteuthis diadema. /19/ Greenish yellow in Spirula. /20/ No luminous bacteria demonstrated in Stomatoteuthis. /21/ Bluish in Oncaea. /22/ Regarding Parapronoe.

295. BIOLUMINESCENCE (Concluded)

Table adapted from data presented in E. Newton Harvey's "Bioluminescence," Academic Press, 1952.

Groups and Typical Luminous Genera	Habitat ¹	Type of Light ²	Knowledge of Histology ³	Necessity for Oxygen ⁴	Luciferin-Luciferase Reaction ⁵	Adenosine Triphosphate Reaction ⁶	Inhibition by Light ⁷	Color of Fluorescence ⁸	Color of Bioluminescence ⁹
37 Mysidacea (Gnathopausia, Mysis, Siriella, Gasterosaccus)	M	E	±						Greenish
38 Schizopoda (Nyctiphanes, Euphausia, Nematoscelis, etc.)	M	I	+		-			Greenish?	Bluish
Decapod shrimp									
39 (Sergestes, Hoplophorus, etc.)	M	I	+		-	-			Greenish yellow
40 (Systellaspis, Plesiopeanaeus, Heterocarpus, etc.)	M	E	+		+	-			Bluish
41 (Xyphocaridina)	F	Bp		+					Bluish
42 Diplopoda (Luminodesmus, Spirobolellus)	T	I, Bs?	-	+	-	-		Blue-green	Greenish white
43 (Trigoniulus)	T	Bp							
44 Chilopoda (Stigmatogaster, Orya, Geophilus, Scoliopterus, etc.)	T	E	+	+	-			Bluish?	Blue-green
45 Collembola (Neanura, Onychiurus, etc.)	T	I ²³	-						Blue-green or greenish yellow
46 Orthoptera (Gryllotalpa)	T	Bp?	-						Greenish white
47 Ephemerida (Caenis, Telonodes)	T	Bp?	-						Pale blue
48 Hemiptera (Fulgora)	T	?	-						White
49 Diptera (Ceroplatys, Platyura, Arachnocampa, etc.)	T	I	±		-	-			Bluish
(Chironomus)	T	Bp							Greenish
51 Lepidoptera (Mamestra, Agrotis larvae, Asteroscopus adult)	T	Bp							Bluish
52 Hymenoptera (Camponotus, Iridomyrmex)	T	Bp?	-						Greenish-yellow
Coleoptera									
53 Lampyridae (Photinus, Photuris, Luciola, Lampyrus, etc.)	TF	I	+	+	+	+	- ²⁴	Greenish yellow ²⁵	Orange (565), yellow (570), or green (550)
54 Phengodidae (Phengodes, etc.)	T	I	+	+	-	-	-	+, yellowish?	Yellow-green
55 Rhagophthalmidae (Diopatra)	T	I	-						Green
56 Drilidae (Diplocladon)	T	I	-						Greenish blue
57 (Phrixothrix)	T	I	+	+	-	-	-		Red and yellow-green
58 Elateridae (Pyrophorus, etc.)	T	I	+	+	+	+	- ²⁴	Yellow	Greenish and orange (518 and 530)
59 Ophiuroidea ²⁶ (Amphiura, Ophiocolex, Ophiopsila, etc.)	M	I	+	+	-	-		Yellow-green	Green
60 Enteropneusta (Ptychodera, Balanoglossus)	M	E	+	+	-	-	-DN ²⁷		Bluish or greenish
61 Tunicata (Pyrosoma, Appendicularia, Salpa, etc.)	M	I or Bs?	+		-	-			Various colors
62 Elasmobranchii (Etmopterus, Laemargus, Centrosyllium, etc.)	M	I	+						Greenish or white
Teleostomi									
63 Macrouridae (Malacocephalus, Coelorrhynchus, etc.)	M	Bs	+	+	+				Greenish blue (510)
64 Gadidae (Physiculus, Lotella)	M	Bs	+						Greenish blue
65 Monacanthidae (Monacanthus)	M	Bs	+		-				Weak bluish
66 Anomalopidae (Photoblepharon, Anomalops, Kryptopteron)	M	Bs	+						Greenish blue
67 Acropomatidae (Acropoma)	M	Bs	+						Bluish white
68 Leiognathidae (Leiognathus, Gazza, Secutor)	M	Bs	+						Bluish white
69 Serranidae (Apogon)	M	I?	+						Bluish green
70 Cerratioidea (Dolopichthys, Ceratias, Linophryne, etc.)	M	Bs?	+						Bluish green or purplish
71 Saccopharyngidae (Saccopharynx)	M	Bs?	-						White
72 Batrachoididae (Porichthys, etc.)	M	I	+						White
73 Stomiatoidea (Echiostoma, Gonostoma, Maurolicus, Polyipnus, Argyropelecus, Chauliodon, Stomus, etc.)	M	I ²⁸	+		-	-		Greenish ²⁹	Yellowish to greenish or bluish
74 Myctophoidea (Myctophum, Diaphus, Lampadena, Neoscopelus)	M	I	+		-	-		Greenish	Bluish or greenish

/1/ F = fresh water; M = marine; T = terrestrial. /2/ Bp = light emission owing to parasitic luminous bacteria; Bs = light emission owing to symbiotic luminous bacteria; E = self-luminosity with extracellular light emission from secreted material; I = self luminosity with intracellular material. /3/ + = cytology of the photogenic cell or histology of the light organ is well known; - = cytology or histology unknown; ± = further study of cytology or histology is desirable. /4/ + = dissolved molecular oxygen is necessary for light production; - = light will appear in complete absence of oxygen (Pt and H₂, or, in excess, hydrosulfite). /5/ + = positive reaction if light appears when a hot water extract of the luminous cells allowed to cool (luciferin) is mixed with a cold water extract of the luminous cells allowed to stand until the light disappears (luciferase); - = a negative reaction. /6/ + = positive reaction if a non-luminous water extract of the luminous tissue containing magnesium emits light when the sodium salt of adenosine triphosphate is added; - = a negative reaction. /7/ + = marked inhibition of luminescence of single-celled organisms or of luminescent extracts by sunlight; - = no marked inhibition; ± = some species show light inhibition, others do not; DN = day-night rhythm of luminescence such that the intact living organism does not luminesce in the daytime even if kept in the dark. /8/ - = no marked fluorescence in near ultraviolet light or after functional activity. /9/ Figures in parentheses are wavelengths of maximum emission where spectrophotometric curves are known. /23/ It has been claimed that the light comes from a fungus in some species. /24/ Intense illumination of the luminous organ inhibits luminescence by affecting nerve stimulation. /25/ The purified luciferin is blue fluorescent in acid, yellow-green in alkali. /26/ The location of luminous organs has been tabulated by G. Grimpe (Tab. Biol. 6:449-501, 1930). /27/ In Ptychodera at Bermuda. /28/ No luminous bacteria demonstrated in Yarella or Polyipnus. /29/ Argyropelecus photophores show no marked fluorescence.

296. INSECTIVOROUS PLANTS: CHARACTERISTICS

Species	Geographic Distribution	Specialized Structures	Remarks
Sarraceniaceae (Pitcher-plants)			
1 <i>Darlingtonia californica</i>	California, Oregon.	Erect, hooded, pitcher-like leaves from 1.5 to 100 cm long, lined with "nectar" glands and hairs. "Digestive" glands absent.	Cf <i>Heliamphora</i> .
2 <i>Heliamphora</i> spp ¹	Northern South America.	Pitcher-like leaves, 30-50 cm long when mature, lined with "nectar" glands and unicellular hairs. "Digestive" glands absent.	Any digestion of animal "prey" must be attributed to adventitious bacterial action because of the reported absence of digestive glands or secretions. Ability of plant to absorb products of digestion not determined.
3 <i>Sarracenia</i> spp ²	Eastern North America.	Pitcher-like leaves, 10-40 cm long when mature, lined with "nectar" glands, unicellular hairs, "digestive" glands; non-cuticular "absorptive" areas present.	Absorption of liquid from pitchers has been demonstrated. pH of pitcher contents in the field varies from 2 to 8. Mature pitchers contain considerable amounts of decayed insect residues. Presence of various enzymes, i.e., maltase, lipase and proteinases, reported in pitcher liquid. Role of bacteria in digestion of animal "prey" not determined. ³
Nepenthaceae (Nepenthes)			
4 <i>Nepenthes</i> (±65 spp) ⁴	Southwest Pacific to Ceylon and Madagascar.	Leaves tendril-like, up to one meter long, terminating in pitcher-like erect hooded cups 5-30 cm long. Pitchers are lined with "nectar" glands, various types of hairs, and "digestive" glands.	Cf <i>Sarracenia</i> .
Droseraceae (Sundews)			
5 <i>Aldrovanda vesiculosa</i>	Europe, Asia, Africa, Australia.	Leaves in whorls of 8, bearing at their tips bilobed "traps" (somewhat similar to <i>Dionaea</i>); inner aspects of lobes bear "secreting" glands and 3 kinds of hairs.	Traps close on appropriate stimulation, as in <i>Dionaea</i> . Insects thus trapped disintegrate. Action of bacteria and enzymes not determined. ⁵
6 <i>Dionaea muscipula</i> (Venus fly-trap)	Peat bogs of North and South Carolina.	Leaves bilobed, with marginal spines and six "trigger" hairs in center of upper surface. Upper leaf-surface bears "nectar" glands and "digestive" glands, both types sessile.	When an insect comes in contact with a trigger hair, the leaf-lobes close rapidly (±0.25 sec), forming with the marginal spines a box-like structure within which the "prey" may be entrapped. Closure is followed by the secretion of an acid substance in which various proteolytic enzymes have been reported. Role of bacteria in digestion uncertain. Absorption of products of digestion reported; significance on nutrition not determined.
7 <i>Drosera</i> (±90 spp)	World-wide.	Leaves orbiculate, spatulate or linear, 2-35 cm long, with tentacles yielding a viscid secretion.	Tentacles inflect to cover insects entrapped in tentacular secretion. Secretion contains sugars and enzymes capable of proteolysis at pH 2. Digestion independent of bacterial action; absorption not clearly demonstrated. ⁶
8 <i>Drosophyllum lusitanicum</i>	Portugal, Spain, Morocco.	Similar to <i>Byblis</i> (cf below) but larger, shrubbier; leaves with stalked "mucilage" glands and sessile "digestive" glands.	Insects captured in mucilaginous secretion. Digestion by secreted enzymes reported, possibly affected by bacteria. Beneficial absorption of proteolytic products reported.
Cephalotaceae (Cephalotus)			
9 <i>Cephalotus follicularis</i>	Australia.	Leaves of 2 kinds: foliage (to 15 cm) and pitcher-like (pitchers to 5 cm long, at right angle to petiole). Pitcher lined with glands and modified stomata which are secretory in function.	Insects entrapped in pitchers disintegrate; whether this is caused by bacterial action, by enzymes produced by the plant, or by both, not determined. No evidence of absorption of products of proteolysis.
Byblidaceae			
10 <i>Byblis gigantea</i> , <i>B. linifolia</i>	Australia.	Semi-shrubs with linear leaves, 10-20 cm long, bearing stalked "mucilage" glands and sessile "digestive" glands.	Small, wingless insects live on leaves and feed on other insects entrapped by mucilage. Digestion of egg-white in contact with secretion of digestive glands reported. Role of bacteria in digestion and absorption of products of digestion not determined.
11 <i>Roridula</i> (2 spp)	South Africa	Leaves equipped with tentacular glands furnishing a "resinous" secretion.	Digestion by bacteria or secreted enzymes not reported. Certain insects habitually feed on entrapped "victims." Cf <i>Byblis</i> .
Lentibulariaceae (Bladderworts)			
12 <i>Genlisea</i> (±10 spp)	Tropical Africa, South America.	Small submersed plants with "foliage" and "trapping" leaves, which are forked at tip, spirally twisted and connected with a basal bulb or receptacle. Grooves formed by twisted portion are transversely ridged and supplied with glandular hairs secreting mucilage.	Disintegrated insect remains are commonly found in grooves of leaves and in basal receptacles. Digestion or absorption of digestive products not determined.
13 <i>Pinguicula</i> (±30 spp)	Northern Temperate and Subarctic Zones.	Rosette plants with entire leaves bearing "mucilage" and "digestive" glands.	Small insects become entangled in mucilage secretions, and leaf margins slowly enroll. Disintegration of insects ensues. Bacterial or enzymatic action uncertain. Absorption of products of digestion not determined. ⁷
14 <i>Utricularia</i> (±275 spp)	World-wide.	Aquatic plants bearing on submersed portions small vesicles or "bladders" lined with glandular hairs. Absorption of water within bladders leads to formation of a partial vacuum; a door closes the bladder. On the outer surface of the door are 4-6 "tripping" hairs or bristles.	When an aquatic insect encounters the tripping hair, the door opens and the intruding water carries the insect into the bladder. After an interval the partial vacuum is reestablished, again setting the trap. Entrapped insects disintegrate and are apparently absorbed. Bacterial action not determined.
15 <i>Biovularia</i> (2 spp)	Antilles, South America.	Cf <i>Utricularia</i> .	Cf <i>Utricularia</i> .
16 <i>Polypompholyx</i> (3 spp)	Australia.	Cf <i>Utricularia</i> .	Cf <i>Utricularia</i> .

/1/ Species: *H. macdonaldae*, *H. minor*, *H. nutans*, *H. tatei*, *H. tyleri*. /2/ Species: *S. adunca*, *S. drummondii*, *S. flava*, *S. jonesii*, *S. minor*, *S. oreophila*, *S. psittacina*, *S. purpurea*, *S. rubra*, *S. sledgii*, *S. variolaris*. /3/ Insect larvae, especially of mosquitoes, have frequently been found growing in the pitcher liquid. This raises questions as to the proteolytic property of the plant secretions. /4/ Five distinct types of nepenthes are: *N. villosa*, *N. lowii*, *N. rajah*, *N. hookeriana*, *N. rafflesiana*. /5/ There is evidence that the plant can grow indefinitely on inorganic nutrients, and no evidence that organic nutrition through the capture of animals is essential for growth. /6/ Plants have survived 15 years, in aseptic culture, on inorganic nutrients + sucrose. /7/ Laplanders reported to use leaf secretion to curdle milk.

297. FACTORS AFFECTING CILIARY ACTIVITY

Part I: CHEMICAL

Cilia cease beating when underlying muscle contracts, resume beating when muscle relaxes.

Ciliated Material		Chemical Factors	Results
Protozoa			
1 Paramecium	Novocaine, 0.5%		Ciliary coordination may be interrupted; partial disappearance of metachronal activity ¹ , or merely slowing of rate.
2	Ions (Na, K, Li, etc.)		Reversal of ciliary beat.
Invertebrates			
3 Actinian larvae, longitudinal band	Ca, Mg ions		Neuromuscular movement inhibited, ciliary movement stimulated.
4 Ctenophora, meridional combs	H, K, and NH ₄ ions		Neuromuscular movement stimulated, then depressed; ciliary movement depressed, then recovers.
5 Veliger (Mollusca) larvae, lobes			
6 Trochophore larvae, peristomal;	Li and Na ions		Neuromuscular movement stimulated, ciliary movement inhibited.
7 Annelida larvae			
8 Nemerteans, surface epithelium	Atropine, 2%	} in sea water	Strong initial stimulus; actively moving after 4 hours.
	Curare, 2%		Strong initial stimulus; actively moving after 4 hours.
	Ether, 2%		Cilia continued beating, undiminished for a long time.
	Lithium chloride, 2%		Cilia at rest after 15 minutes.
	Magnesium chloride, 2%		Muscular contraction inhibited, but not cilia.
	Nicotine, 2%		Cilia brought to rest after a few minutes.
	Pilocarpine, 2%		Very active ciliary movement, undiminished after 2 hours.
	Strychnine, 2%		Ciliary movement stimulated initially, then becomes inactive.
16 Pecten yessoensis (Mollusca), terminal cilia on end of gill	pH 3.7 ± 0.1: HCl at 13°C 3.8 ± 0.4: H ₃ PO ₄ at 20°C 5.45 ± 0.15: CH ₃ COOH at 20°C 5.5 ± 0.5: H ₂ CO ₃ at 20°C 6.15 ± 0.05: H ₂ CO ₃ at 13°C		Stop cilia in 1 minute; order of efficiency: H ₂ CO ₃ >CH ₃ COOH>H ₃ PO ₄ >HCl.
21 Anodonta (Mollusca), gill	Caffeine, 2%		Ciliary movement accelerated for 3 minutes, ceased in 6 minutes.
	Chloral hydrate, 0.5%		Cilia quiet in 4 to 5 minutes.
	Novocaine, 1%		Cilia quiet in 9 minutes.
	Pilocarpine HCl, 1.5%		Metachronal activity ¹ continues until cilia become quiet (2 minutes).
	Strychnine sulfate, 1%		Cilia quiet in 10 minutes.
	Veratrine sulfate, 1-1.5%		Metachronal activity ¹ continues until cilia quickly cease movement.
Vertebrates			
27 Frog, buccal membrane (excised)	Acetic acid vapor } gas Ammonia vapor, 1.5% } chamber Alcohol, amyl } butyl } 1:10 dilution ethyl } in normal methyl } saline propyl }		Ciliary movement stimulated initially, then stopped. Initial strong movement of cilia, then cessation. Cessation of ciliary movement in 18 minutes. Cessation of ciliary movement in 3 hours. Cessation of ciliary movement after 30 hours. Cessation of ciliary movement after 30 hours. Cessation of ciliary movement after 25 hours. Cilia brought to rest. Ciliary activity slowly stimulated, then became vigorous. Reversal of ciliary beat.
	Acids Alkalies (KOH, NaOH) Ions (Na, K, Li, etc.) Sodium bicarbonate, conc. vapor Sodium chloride, 0.3-0.5% Sodium chloride, 0.5%, or blood serum in gas chamber, + CO ₂		Quick cessation of ciliary movement. Cilia beat all day, no cessation. Initial cessation of ciliary movement, followed by vigorous activity; cilia beat longer in dilute solutions of CO ₂ .
40 Frog, esophageal mucosa (in situ)	Benzedrine, 0.1% Ephedrine HCl, 0.1% m-Synephrine HCl, 0.1%		46 to 52% depression of ciliary movement. 25 to 32% depression of ciliary movement. 17 to 25% depression of ciliary movement.
43 Frog, esophagus (in vitro)	Alcohol Chloroform Ethylene Nitrous oxide Sodium amytal Sodium veronal		Slight depression of ciliary activity. Depressed ciliary activity. Initial stimulation of ciliary activity. No effect on ciliary activity. Depressed ciliary activity. Depressed ciliary activity.
49 Frog, pharynx	Acetylcholine, 0.001% Arecoline, 0.01% Atropine, 0.001% Caffeine, 2% Chloral hydrate, 0.5% Chloretone, 0.1% Choline, 1% Epinephrine, 0.001% Ether, 7.3% Physostigmine, 0.01% Pilocarpine, 0.01% ² Strychnine sulfate, 1% Veratrine sulfate, 1-1.5%		No stimulation to moderate stimulation of ciliary activity. Strong stimulation of ciliary movement. No effect on ciliary activity. Ciliary movement accelerated for 3 minutes, ceased in 6 minutes. Cessation of ciliary movement in 5 minutes. Cessation of ciliary movement in 5 minutes. Slight stimulation of ciliary activity. Slight stimulation of ciliary activity. Cessation of ciliary movement in 5 minutes No effect to strong stimulation of ciliary activity. Strong stimulation of ciliary activity. Ciliary movement ceased in 10 minutes. Metachronal activity ¹ continues until cilia become quiet.
62 Frog, pharynx tissue culture	Cresols, o-, m-, and p- Phenol, cresol, thymol α- and β- Naphthol Zootoxin, (Lytt spp): cantharidin crystal Zootoxin, fish (Synancea verrucosa), diluted Zootoxin, toad dermal glands, 1:10,000 dilution		m-Cresol accelerated, o- and p- retarded, ciliary activity. Toxic effect on ciliary activity decreases in order listed. Toxic effect on ciliary activity decreases in order listed. Slight irritation; finally a decrease in ciliary activity, with separation of individual cells, cilia still beating. Acceleration of ciliary movement followed by gradual reduction. Intense acceleration of ciliary activity, followed by depression.
68 Cat, upper bronchi and trachea	Morphine, 0.125 mg/kg, and codeine, 0.75 mg/kg		Apparently little or no effect on ciliary movement.
69 Ox, tracheal tissue (excised)	Acetylcholine chloride, veratrine SO ₄ , caffeine, pilocarpine HCl, strophanthin Barium chloride, chloral, cocaine HCl, quinine HCl, saponin		Accelerating effect decreases in order listed. Retard ciliary movement.

^{1/} Metachronal activity: characteristic ciliary beating of any ciliated cell or tissue in one direction in a regular sequence. ^{2/} Pilocarpine, 1.5%, caused ciliary movement to cease in 6 minutes.

297. FACTORS AFFECTING CILIARY ACTIVITY (Concluded)

Part I: CHEMICAL (Concluded)

Cilia cease beating when underlying muscle contracts, resume beating when muscle relaxes.

Ciliated Material		Chemical Factors	Results
		Vertebrates (concluded)	
71	Man, dog, guinea pig: mucous membrane strips, upper respiratory tract (man and dog tissue strips in chamber, guinea pig tissues in situ)	Cocaine, 10-20%	Ciliary activity slowed; good recovery (5% cocaine does not decrease, may even increase, ciliary activity).
72		Ephedrine HCl, 3%	Not harmful, may increase activity.
73		Epinephrine HCl, 0.1%	Definitely detrimental, slowing to stoppage.
74		Eucalyptol, 1%	Depresses or stops ciliary activity, with fair or no recovery (0.5% no harmful effect).
75		Menthol, 0.5%	Mildly depresses ciliary activity (1% more depressing than 0.5%).
76		Mercurochrome, 2%	Definitely detrimental, slowing to stoppage of ciliary activity.
77		Silver nitrate, 0.5%	Immediately detrimental to ciliary activity; no recovery.
78		Silver proteinate, 5, 10, and 20%	Initial acceleration of ciliary activity, then retardation.
79		Thymol, 0.5-1%	Detrimental to ciliary activity, or cessation, with fair or no recovery.
80		Zinc sulfate, 2%	Definitely detrimental, slowing to stoppage.
81	Man, nose (extirpated mucous membrane)	Chlorbutanol	Slows, stops cilia; recovery from weak solutions.
82		Penicillin (5000 units/ml normal saline) applied directly	Non-irritating to cilia.
83		Tuamine sulfate, 1%	No slowing of cilia during 41 minutes of observation.
84		Turamine sulfate, 1%	Average slowing time 97 minutes; recovery from weaker solutions.
85		Sulfadiazine, 2%, in triethanolamine and butoben	Ciliary movement stops, recovers when washed; effect caused by solvent (?).
86		Sulfadiazine, sulfanilamide, sulfathiazole, as powders	No effect on ciliary movement.
87		Sulfanilamide, in saline	No permanent deleterious effect.
88		Sulfathiazole, sodium, 5% (isotonic solution)	In 50% of tests cilia did not recover after immersion; caused by pH (10.17) (?).

Part II: PHYSICAL

Ciliated Material		Physical Factors	Results
1	Paramecium	Electricity: Direct current, 0.1-0.15 mA in water.	Animal stopped with anterior end toward the positive pole.
2	Beroe spp (Ctenophora), swimming plate	2 mA/ml passed longitudinally, at <20°C.	Inhibition effect, from cathode.
3	Turtle trachea	A C electrodes on trachea.	No change in ciliary frequency.
4	Paramecium	Hydrostatic pressure: 1-300 atmospheres.	No effect on ciliary rate.
5	Mytilus (Mollusca), lateral cilia of gill	400-600 atmospheres.	Ciliary action ceased.
6		Gill in pressure bomb; pressures up to 1000 or 3000 lb/sq in.; (stroboscopic measurement).	Ciliary rates increase immediately, 7-20%; gradual return to normal.
7		Incr. in successive equal steps of pressure.	Increase in ciliary movement constant.
8		Pressure 5000 lb/sq in.	Basic ciliary frequency falls rapidly.
9		Pressure 6000 lb/sq in.	Irreversible damage.
10		Sudden decrease from 5000 or 1000 to 0 lb/sq in.	Immed. decrease of 3-25% in ciliary movement, with gradual return to normal.
11	Frog, pharynx tissue culture	From -7 to +7 atmospheres.	Little or no effect on ciliary rate.
12	Frog, pharynx tissue culture	-8 atmospheres.	Slight decrease in rate.
13		Light: 300-400 mμ (UV), short exposure.	Intense acceleration of ciliary movement.
14		500-620 mμ.	No effect.
15		650-722 mμ.	Temporary acceleration of ciliary movement.
16	pharynx in toto on slide	Darkness.	Cilia come to rest after about 45 minutes.
17	Frog, pharynx in toto on slide	Light: after cilia come to rest in darkness.	Activity resumed in about 2 minutes.
18		Mechanical influences: Floating cells.	Stimulation.
19		Base line: no substances.	Cilia inactive.
20		Ringer's solution.	Cilia active until fluid is removed.
21		Carbon particles.	Cilia active until particles are removed.
22		Camphor crystal.	Cilia active in front of crystal, inactive after its passage.
23	Paramecium bursaria	Radiation: X-rays above 200,000 roentgens.	Decreased ciliary activity.
24	Frog, pharynx tissue culture	X-rays, 1,000,000 roentgens.	Ciliary activity decreased to very low level.
25		Radium bromide, 100 mg, 3 hr.	Temporary inhibition.
26		X-rays, 1-4 million roentgens.	Ciliary movement completely inhibited.
27	Oyster, Japanese (Ostrea circumpicta)	Osmotic effects: Sea water, dil. to 50% normal salinity.	Ciliary activity stimulated.
28	Frog, buccal membrane, excised	Sea water, dil. from 50 to 20% normal salinity.	Ciliary activity declines to nearly zero.
29		Distilled water.	Initial strong stimulation of cilia; cells develop vesicles in 1 minute; ciliary movement ceases in 5 to 10 minutes.
30	Oyster (intact), feeding organs	Temperature: 4-6°C	Decreased ciliary activity; normal feeding above this range, almost none below.
31	Modiolus (Mollusca) gill, lateral cilia	25-30°C	Optimum for ciliary activity; coordination of cilia decrease at temp below 15°C and above 25°C.
32		10-35°C	Ciliary vibration rate increases with temperature, from 3.5-15.8/second.
33		20-27°C	Ciliary rate increases.
34	Frog, pharynx in toto on slide	28°C	Ciliary rate increases notably.
35		35-38°C	Maximum increase in ciliary rate.
36		42°C	Cilia stop moving.
37		7-12°C	Cilia stop moving.
38	Rabbit, sinus in situ	18-33°C	Ciliary activity greatest (7 to 10 vibrations/second).
39		40°C	Movement of cilia greatly retarded.
40		43-44°C	Cilia stop moving; no recovery.

298. AMEBOID MOVEMENT: RATE

In this table ameoid movement means actual locomotion of the ameba by means of ectoplasmic contraction, protoplasmic streaming, or both.
f = fresh water; s = sea water.

Species ¹	Dimensions		Number of Nuclei ²	Habitat	Average Rate of Movement ³		Optimum (Highest Rate) Temp. °C
	Length μ	Width μ			μ /sec	°C	
1 Trichamoeba, Pantin's "A"	120	50	10-20	s	1.9	22	20-24
2 Trichamoeba, Pantin's "B"	150	135		s	3.3	20	20-24
3 Trichamoeba, caerulea	150	42		f	1.9	22	
4 T. clava	100	25		f	3.2	25	34-36
5 T. fusa	175	40		f	11.4	22	
6 T. gumia	100	41	10-20	s	2.0	22	
7 T. limax ⁴				f	1.0		
8 T. osseosaccus	125	32		f	2.5	22	
9 T. pallida	60	12		s	2.0	27	
10 T. schaefferi	175	33		s	5.9	22	20-24
11 T. sphaerarium	25	6	10-20	s	1.1	27	
12 Pelomyxa clara	175	100		f	3.3	22	28.5-31
13 P. minima	78	35		f	0.55	23	34-36
14 P. palustris	580	200		f	5.6	23	
15 P. scheidti	75	33		f	1.6	22	
16 Striolatus tardus	60	16	25	s	0.5	27	
17 Polychaos dubia	400	300	to 300	f	3.3	22	
18 Metachaos discoides ⁶	450	45		f	2.5	26	34-36
19 M. fulvum ⁶	70	24		s	2.5	27	
20 M. granulosa ⁶	225	70		f	4.2	26	
21 M. gratum ⁶	200	60		f	2.5	22	
22 M. oxyuris ⁶	130	27	10-20	f	1.5	22	
23 M. rarum ⁶	125	53		f	1.6	22	
24 Chaos chaos	1800	130		f	12.0	23	
25 Chaos nobilis	725	95		f	1.0	23	
26 Amoeba proteus pallas ⁷	600	85		f	10.0	21	
27 A. proteus pallas ^{6, 7, 8}			10-20	f	10.4	22	34-36
28 A. proteus pallas ^{6, 7}				f	4.6 ⁷	23	
29 A. proteus ^{6, 9}	460	65		f	6.8	23	
30 Flabellula citata	20	37		s	2.0	25	
31 F. citata				s	1.2	27	34-36
32 F. crassa	50	58	10-20	s	0.4	27	
33 F. mira	25	20		s	1.2	27	
34 F. mira				s	0.5 ¹⁰	23	
35 F. pellucida	30	80		s	0.9	27	
36 Mayorella augusta	250	74		f	1.7	22	
37 M. bigemma	200	110	25	f	2.6	25	
38 M. bulla	100	51		f	1.7	22	
39 M. conipes	45	23		s	0.8	25	34-36
40 M. conipes				s	2.0	27	
41 M. crystallus	30	22		s	0.5	27	
42 M. gemmifera	50	28	25	s	0.7	27	
43 Vexillifera aurea	80	31		s	0.8	27	
44 Astramoeba stella	40	18		f	0.4	22	
45 A. torrei	120	55		f	1.2	27	
46 Gibbodiscus gemma	35	30		s	0.6	27	
47 Flamella magnifica	50	50	25	s	0.8	27	
48 Dactylosphaerium acuum	60	60		s	0.3	27	
49 Pelomyxa lentissima	100	50		f	0.03	27	
50 Rugipes bilzi	70	34		f	1.7	23	
51 R. vivaz	12	8		s	0.4	27	
52 Thecamoeba hilla	80	45	25	s	2.5	27	
53 T. rugosa	70	35		s	0.5	27	
54 T. verrucosa ¹¹	150	90		f	0.5	25	34-36
55 Hyalodiscus aureus	80	70		s	0.4	21	
56 H. elegans	40	40		s	1.3	21	
57 Cochliopodium clarum	40	39	25	s	0.3	21	
58 C. gulosum	80	55		s	0.4	21	

/1/ Grouped according to characteristic body shape during locomotion. General body shape: Lines 1-16, clavate; Lines 17-29, antler-shaped with large indeterminate pseudopods; Lines 30-49, 55-58, fan-shaped to triangular with small determinate pseudopods; Lines 50-54, oval without pseudopods. /2/ Unless otherwise indicated, the amebas listed have one nucleus, occasionally 2-4, except Flamella magnifica (Line 47) which has no formed nucleus. /3/ Rates at culturing temperatures during well-coordinated movement in clear culture fluid on glass surfaces, except Amoeba proteus pallas (Line 28), which was in 0.001 N NaCl after washing in distilled water. /4/ Original report in literature: Trichamoeba limax = Amoeba limax. /5/ Occasionally has only one nucleus. /6/ Rates determined while in clavate shape. /7/ Amoeba proteus pallas is North American name for Chaos diffluens. /8/ Mixture of Amoeba proteus pallas and Metachaos discoides. /9/ Chaos nitida is European name for Amoeba proteus. /10/ Mean rate. /11/ Original report in literature: Thecamoeba verrucosa = Amoeba verrucosa.

299. PROTOPLASMIC STREAMING

Protoplasmic streaming as considered in this table includes the shuttle-type flow of protoplasm in slime molds, cyclosis in higher plants, and streaming of protoplasm within rigid cell walls of algae. Streaming rates have been studied by use of many techniques, and results vary according to methods and conditions of measurement. Values were interpolated, where necessary, for comparison from graphic and tabular data in the literature. Parts I, II, and III show the effect of temperature on rate of streaming. Part I shows typical rates; Part II gives the temperature coefficient of *Avena* (oat) coleoptile. Part III reveals the effect of sudden changes of temperature, with estimates of temperature sensitivity. Because energy available for streaming has been associated with respiration, the effect of oxygen concentration is shown in Part IV. In Part V is presented the effect of various agents generally known specifically to affect respiration. Part VI demonstrates the effect of light on non-chlorophyll containing cells of *Avena* coleoptile observed in the orange-red phototropically inactive spectral region after exposure to various doses of blue light (4360 Å), at 23°C. Data show the fitness of the product rule (intensity x time), as well as the effect of total energy (dosage). Part IX shows the spectral sensitivity of this effect. The term "chemodinesis" (Part VII) is used to describe the action of certain alpha amino acids and other compounds which in very high dilution initiate protoplasmic streaming in leaf cells of *Vallisneria*. The lower concentration thresholds are presented in Part VIII. The action of various other agents on streaming is indicated in part VIII.

Part I: EFFECT OF TEMPERATURE

Material (Investigator)	Rate of Streaming, μ /sec							
	5°C	10°C	15°C	20°C	25°C	30°C	35°C	40°C
1 Chara foetida (Velton, 1876)	20.4	26	38	42	52	76	93	72
2 Elodea canadensis (Velton, 1876)	4.8	7.7	8.8	10.5	11.5	13.3	16.7	0
3 Vallisneria spiralis (Velton, 1876)	4.7	8.7	15.1	20	26	31	38	
4 Nitella sp (Ganong, 1908)	10.5	15.3	20	27	34	43	47	37
5 Chara foetida (Lambers, 1926)	11.2	24.5	41	56	74	90		
6 Nitella mucronata (Lambers, 1926)	12.7	28	41	60	75	96	109	
Avena coleoptile (Bottelier, 1934)								
7 90 hr old	3.4	4.8	7.0	8.2	8.3	8.5		
8 200 hr old	3.6	5.7	7.9	10.4	12.8	15.8		

Part II: TEMPERATURE COEFFICIENT

Temp, °C	Avena Coleoptile	
	Age: 90 hr Q ₁₀	Age: 140-200 hr Q ₁₀
1 5-10	1.8-2.1	1.9-2.2
2 10-15	1.8	1.8
3 15-20	1.1	1.8
4 20-25	1.1	1.7
5 25-30	0.9	1.5
6 30-35	0.7	1.1
7 35-40	0.9	

Part III: EFFECT OF SUDDEN CHANGES OF TEMPERATURE

T₀ = initial temperature; T = final temperature prevailing during the test; R₀ = average streaming rate (μ /sec) at T₀

Temp. °C			R ₀	Rate of Streaming, μ/sec, at Specified Interval (min)												Sensitivity ¹
T	T ₀	10		20	30	40	50	60	70	80	90	100	110	120		
Nitella flexilis																
1	24.5	13.8	28.5		55	55	55	55	55	55	55	55	55	55		
2	31.5	13.8	28.5		80	80	80	80	80	80	80	80	80	80		
3	37.5	13.8	28.5		99	99	99	99	99	99	99	99	99	99		
4	12.8	19	55		36	36	36	36	36	36	36	36	36	36	$\frac{100}{12} = 8.3$	
5	12.8	22	62.5		36	36	36	36	36	36	36	36	36	36		
6	12.8	24.3	70		36	36	36	36	36	36	36	36	36	36		
7	12.8	26	74		24	28	32	34	36	36	36	36	36	36		
8	20	25	86		71	71	71	71	71	71	71	71	71	71	$\frac{100}{6} = 16.6$	
9	20	27.5	93		64	68	69	70	71	71	71	71	71	71		
10	20	30	100		62	65	66	68	69	70	71	71	71	71		
11	20	35	114		45	50	52	54	56	58	60	62	63	64		
12	25	30	100		83	83	83	83	83	83	83	83	83	83	$\frac{100}{9} = 11.1$	
13	25	32.5	104		83	83	83	83	83	83	83	83	83	83		
14	25	33	106		83	83	83	83	83	83	83	83	83	83		
15	25	35	113		77	80	82	82	83	83	83	83	83	83		
16	25	38.5	125		71	74	76	77	78	80	81	81	82	83		
17	25	40	131		25	40	48	54	58	62	65	68	70	72		
Avena coleoptile																
18	13	21	12	6.0	6.2	6.4	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	$\frac{100}{7.5} = 13$	
19	13	24	12.8	0.9	0.1	2.1	3.2	4.4	5.1	5.8	6.3	6.9	7.5	7.6		
20	13	28	12.6	12.6	0	0.4	1.2	2.6	4.5	5.8	6.6	7.3	7.7	7.7		
21	21	25	11	4.2	9.1	9.9	10.2	10.3	10.3	10.3	10.3	10.3	10.3	10.3	$\frac{100}{3.5} = 30$	
22	21	27	10	0	4.5	9.9	11.9	12.1	12.1	12.1	12.1	12.1	12.1	12.1		
23	21	36	3.4	0	0.1	0.1	0.2	0.1	0.2	0.1	0.1	0.2	0.4	1.4		

/1/ Sensitivity = 100 ÷ maximum temp difference giving no rate lag.

Part IV: EFFECT OF OXYGEN

Material	O ₂ Conc. % Sat. (ml/L)	Streaming Rate	Per Cent of Normal Rate of:		Material	O ₂ Conc. % Sat. (ml/L)	Streaming Rate	Per Cent of Normal Rate of:	
			Streaming	Respiration				Streaming	Respiration
1 Physarum	21(6.27)	Normal	100	100	12 260 hr old, 26°C	21(5.85)	13.4 μ /sec	100	
2 polycephalum,	2.4(0.72)	Normal		60	13 260 hr old, 21°C	4(1.23)	9.0 μ /sec	88	
3 at 22°C	1.0(0.30)	Reduced		30	14 260 hr old, 26°C	4(1.02)	9.1 μ /sec	68	
4	0.3(0.08)	Reduced		9					
5	0.1(0.03)	Reduced		3					
6	0(0)	Reduced	0	0					
					O ₂ Conc. % Sat. (ml/L)				
7 Avena coleoptile					15 80 hr old, 25°C	10.8-14.6 ¹ (3.1-4.1)		100	100 ²
8 96 hr old, 21°C	100(30.4)	9.9 μ /sec	99		16 80 hr old, 25°C	14.6 ¹ -21(4.1-5.7)			50 ²
9 96 hr old, 26°C	100(27.8)	10.1 μ /sec	132		17 95 hr old, 25°C	10.8-18.2 ¹ (3.1-5.3)		100	100 ²
10 96 hr old, 21°C	21(6.32)	10.0 μ /sec	100		18 95 hr old, 25°C	18.8 ¹ -21(5.3-5.7)			50 ²
11 96 hr old, 26°C	21(5.85)	10.1 μ /sec	100		19 130 hr old, 25°C	11.6-12.4 ¹ (3.2-3.5)		100	100 ²
12 260 hr old, 21°C	21(6.32)	10.2 μ /sec	100		20 130 hr old, 25°C	12 ¹ -21(3.5-5.7)			50 ²

/1/ Critical O₂ tension. /2/ Rates uniform within indicated O₂ ranges, there being a sharp change in rate at the critical oxygen tension.

299. PROTOPLASMIC STREAMING (Concluded)
Part V: EFFECT OF CHEMICAL RESPIRATORY AGENTS

Agent		Residual Respiration % Control	Effect on Streaming
Physarum polycephalum ¹			
1	KCN, $1 \times 10^{-4}M$	77	
2	KCN, $5 \times 10^{-4}M$	47	
3	Air, control ²	100	+++ (indefinitely).
4	Air + KCN, $1 \times 10^{-3}M^2$	15.1	+++ (after 7 hr).
5	2.4% O ₂ , control ²	59	+++ (indefinitely).
6	2.4% O ₂ + KCN, $1 \times 10^{-3}M^2$	5.2	
7	After 2 hr in 2.4% O ₂ and 3 hr in KCN ²		+++
8	After 5 hr in KCN (2 hr of which in air) ²		++
9	1.0% O ₂ , control ²	30.5	
10	1.0% O ₂ + KCN, $1 \times 10^{-3}M^2$	1.4	
11	After 2 hr in 1.0% O ₂ and 3 hr in KCN ²		+++
12	After 7 hr in KCN (2 hr of which in air) ²		+
13	DNP, $2 \times 10^{-4}M$	122-137	Stopped within 5 min (reversible).
14	DNP, $1.25 \times 10^{-4}M$	138-143	Stopped within 10 min (reversible).
15	Na iodacetate, $5 \times 10^{-3}M$	35	Not stopped until disintegration occurs.
16	NaN ₃ , $1 \times 10^{-4}M$	30	Stopped quickly (reversible).
17	Na pyrophosphate, $2(10^{-2} \text{ to } 10^{-4}M)$	No effect	No effect.
Avena coleoptile			
18	KCN, $3 \times 10^{-4}M$		53% ³ (reversible).
19	KCN, $1 \times 10^{-2}M$	54-67	53-61% ³ (reversible).
20	KCN, $1 \times 10^{-1}M$		Stopped within 22 min (irreversible).
21	DNP, $5 \times 10^{-6}M$		100% ³ .
22	DNP, $1 \times 10^{-5}M$	100 ⁴	
23	DNP, $2.5 \times 10^{-4}M$	37 ⁴	52% ³ .
24	DNP, $5 \times 10^{-4}M$	3 ⁴	Stopped within 22 min (irreversible).
Nicotiana tabacum ⁵			
25	KCN, $8 \times 10^{-4} \text{ to } 2 \times 10^{-3}M$	40-50	40% ³ .

/1/ Streaming measurements not absolute because of irregular change of rate and direction of movement. Relative rates presented as number of plus signs. /2/ Data applicable to same plasmodium. /3/ Per cent of control. /4/ Rates sustained 30 minutes after rinsing. /5/ Data applicable to marginal cells of leaf.

Part VI: EFFECT OF VARIOUS DOSES OF LIGHT (4360Å): AVENA COLEOPTILE

Dosage ¹ ergs/sq cm				Illumination Intensity ergs/sq cm/sec				Time sec				Reaction ²			
1	10	2	5	-29	14	110	11	10	-118	26	440	11	40	-84	
2	12	23.6	0.5	-54	15	118	23.6	5	-92	27	472	23.6	20	-54	
3	20	2	10	-49	16	120	2	60	-112	28	480	2	240	-107	
4	20	5	4	-67	17	142	23.6	6	-97	29	600	5	120	-69	
5	22	11	2	-74	18	160	5	32	-103	30	660	11	60	-22	
6	24	23.6	1	-75	19	180	2	90	-160	31	746	23.6	32	-15	
7	40	2	20	-72	20	189	23.6	8	-136	32	944	23.6	40	+32	
8	47	23.6	2	-87	21	220	11	20	-169	33	1320	11	120	+132	
9	55	11	5	-70	22	236	23.6	10	-105	34	1420	23.6	60	+42	
10	66	11	6	-74	23	240	2	120	-118	35	2100	23.6	90	+28	
11	80	2	40	-91	24	360	2	180	-104	36	2800	23.6	120	+26	
12	88	11	8	-78	25	378	23.6	16	-81	37	4200	23.6	180	+4	
13	94	23.6	4	-77											

/1/ Energy (intensity x time). /2/ Algebraic sum (average of 1-20 separate experiments for each energy value) of per cent departures from normal rate. Negative values indicate a decrease in streaming; positive values, an increase.

Part VII: CHEMODINESIS: VALLISNERIA

Compound	Molarity	Threshold %	Compound	Molarity	Threshold %	Compound	Molarity	Threshold %
1 L-Histidine	5×10^{-8}	7.7×10^{-7}	5 Benzoic acid	1×10^{-5}	1×10^{-4}	8 Histamine	8×10^{-5}	4×10^{-4}
2 L-Asparagine	1.5×10^{-6}	2×10^{-6}	6 Cinnamic acid	1×10^{-5}	1×10^{-4}	9 Na-β-indole acetate	1×10^{-4}	1.9×10^{-3}
3 L-Alanine	1×10^{-6}	8.9×10^{-6}	7 Salicylic acid	1×10^{-5}	1×10^{-4}	10 Leaf extract (Vallisneria)		2.5×10^{-5}
4 p-Galacturonic acid	5×10^{-6}	1×10^{-4}						

Part VIII: EFFECT OF CERTAIN PHYSICAL AND CHEMICAL AGENTS

Agent	Material	Effect on Streaming	Agent	Material	Effect on Streaming
1 Ethyl chloride, 25%	Physarum	Stops in 10-15 sec.	15 3-Indoleacetic acid, 0.005-0.5 mg/L	Avena	Increases up to 13% ¹ .
2 Ethyl chloride, 18%	Physarum	Stops in 20 sec.	16 Heavy metals, $5 \times 10^{-6} \text{ to } 5 \times 10^{-2}M$	Physarum	Decreases: Ag>Hg>Cd>Tl>Cu>Pb>Zn>Y>Sr>La>Rb.
3 Ethyl chloride, 5%	Physarum	No effect.			
4 LiCl ₃ , 0.1 M	Chara	Stops in 5 hr.			
5 CaCl ₂ , BaCl ₂ , 0.1 M	Chara	Stops in 6 hr.			
6 Ethyl ether, low conc.	Physarum	Accelerates.			
7 Ethyl ether, high conc.	Physarum	Inhibits.	17 pH 3-8	Chara	Max. at pH 5.5 & 7.
8 Ethyl ether, 10-32 mg/L	Avena	Inhibits.	18 pH 5-7	Hordium ²	Max. at pH 5.8 & 6.4.
9 Sodium chlorate	Elodea	Inhibits.	19 Hydrostatic pressure, 400 atmos.	Nitella	Stops (reversible).
10 Menotoxin extract	Elodea, Nitella	Stops.	20 Hydrostatic pressure, 600 atmos.	Elodea	-50% (reversible).
11 Quinine hydrochloride, 1:150	Physarum	Accelerates, then stops.	21 X-radiation, 25-70,000 r.	Tradescantia	Inhibits.
12 Morphine, 1:20	Physarum	Stops in 2-3 min.	22 Electric current, 3.1×10^{-8} amps.	Chara, Nitella	Stops temporarily.
13 Colchicine, 1:1000	Elodea	Accelerates.	23 Electric current, 1 to 5×10^{-6} amps.	Avena	Inhibits, stops temporarily.
14 Ethylene chlorhydrin, 0.025-0.075 M	Elodea, Nitella	Accelerates.			

/1/ No effect has been reported at concentration of 0.01-10 mg/L. /2/ Observation from cells of root hairs.

Part IX: EFFECT OF VARIOUS WAVE LENGTHS: AVENA COLEOPTILE

Wave Length Å	Dosage ¹	Reaction ²	Equivalent Energy ³	Sensitivity	Wave Length Å	Dosage ¹	Reaction ²	Equivalent Energy ³	Sensitivity
1 3660	270	-46	16	6	6 4360		Cf Part VI		100
2 760	-85	90	12		7	230	-16	7	3
3 21	-15	7	33		8 5460	240	-15	7	3
4 4550	67	-33	13	20	9	1790	-60	30	1.7
5 190	-90	95	50		10 5780	9000	+1		<1
					11 6200	Cf Fn 4	+1		<1

/1/ Intensity x time. /2/ Algebraic average of per cent departures from normal rate. Negative values indicate a decrease in streaming; positive values, an increase. /3/ Equivalent energy required at 4360 Å for comparable effect. /4/ Approximately 70 ergs/sq cm/sec.

300. TRANSPIRATION RATES

Factors influencing transpiration include solar radiation, humidity, temperature, and wind. Part I (Section 1) presents the rate of water loss as influenced by these conditions. Certain soil factors indicated in Part I (Section 2) are involved in water absorption, giving a corresponding effect on transpiration. Part II gives hourly and day and night variations of corn (Zea mays). Values are averages for 30 days during July and August, Nebr. Agr. Exp. Sta. Part III reveals diurnal transpiration of mullein (Verbascum thapsus). Part IV gives the total water loss during the growing season. Part V denotes the water required to produce one gram of dry matter, the transpiration ratio.

Part I: TRANSPIRATION RATES: VARIOUS CONDITIONS

Section 1.				
Species	Temp °C	Light	RH ¹ %	Water Loss g/sq dm/hr
Herbaceous Plants				
1 Corn (Zea mays)		12-2 PM		2.5
2 Sorghum, kafir (Sorghum vulgare)		12-2 PM		2.2
3 Sorghum, milo (S. vulgare)		12-2 PM		4.3
4 Sunflower (Helianthus annuus)	27		22 ³	0.7;0.9
5	38		22 ³	1.2;2.8
6	49		22 ³	2.1;4.9
7 Tobacco (Nicotiana tabacum)	23-26		68	1.5
8	37-38		68	3.6
Woody Plants				
9 Box elder (Acer negundo)	38	Shade	32	0.6
10 Buckeye (Aesculus glabra)	38	Shade	32	0.7
Germander (Teucrium scorodonia)				
11 Sun leaves	26-30	Sun	38-46	0.7
12 Shade leaves	26-30	Sun	38-46	0.4
13 Sun leaves	18-19	Shade	75-76	0.3
14 Shade leaves	18-19	Shade	75-76	0.1
15 Maple (Acer saccharinum)	13-17		58-78	1.0
16 Oak (Quercus rubra)	38	Shade	32	0.8
17 Orange (Citrus sinensis)	21-38		40-98	0.2
18 Peach (Prunus persica)	21-38		40-98	0.7
19 Pecan (Carya illionensis)	24	Day	45-60	1.07
20	20-23	Night	61-65	0.09
21 Pine (Pinus ponderosa)	13-17		58-78	0.2
22 Pineapple (Ananas comosus)	31		59	2.0
23	24		85	0.03
24 Spruce (Picea engelmannii)	13-17		58-78	0.2
25 Sycamore (Platanus occidentalis)	38	Shade	32	0.8
26 Walnut (Juglans nigra)	75	Day	45-60	0.09
27	68-73	Night	61-65	0.08

/1/ Relative humidity. /2/ g per sq dm leaf surface per hr. /3/ Wind, 6 mi/hr.

Section 2.		
Species	Specified Condition	Water Loss mg/sq cm/hr ¹
1 Apple (Pyrus malus)	Straw mulch	17.2
2	Without mulch	14.3
3 Cotton (Gossypium herbaceum)	Soil of low salt conc.	15
4	With 0.8% Ca (NO ₃) ₂	1.6
5	10 AM - 2 PM	4.5
6 Euphorbia (Euphorbia capitellata)	Evaporation 0.01 g/sq cm ²	
7	10 PM - 7 AM	0.1
8	Evaporation 0.01 g/sq cm ²	
9	Soil temp 27°C	4.6
10 Grapefruit (Citrus grandis)	Soil temp 35°C	3.1
11 Houseleek (Sempervivum howorthii)	Wind velocity 1100 cm/sec	0.6
12	Wind velocity 570 cm/sec	0.2
13 Pepper (Capsicum annuum)	Soil moisture 50% ³	3.5
14	Soil moisture 25% ³	1.1
15 Wheat (Triticum aestivum)	Good loam soil	2.1
16	Poor soil	1.1

/1/ Mg per sq cm leaf surface, per hr. /2/ Evaporation from free water surface. /3/ Per cent water holding capacity of soil.

Part II: TRANSPIRATION RATES; CORN: DIURNAL VARIATION

Period	Temp °C	RH ¹ %	Wind mi/hr	Water Loss	
				Per Plant ²	Evaporation ³
				g	g
1 8 AM	23.1	80	6	84	4.8
2 9	25.5	73	7	111	7.7
3 10	27.6	67	8	167	11.6
4 11	29.3	63	8	215	15.0
5 12	30.8	58	9	279	19.2
6 1 PM	31.9	55	9	329	23.7
7 2	32.7	53	9	356	24.5
8 3	32.9	52	9	354	23.8
9 4	32.8	50	9	343	22.2
10 5	32.2	51	8	294	18.5
11 6	31.2	53	8	217	14.1
12 7	28.4	58	7	132	10.2
13 8	27.6	64	7	64	6.4
14 Av. for day	29.8	59.8	8	226	15.5
15 Av. for night	22.7	81.5	6	16	2.3

/1/ Mean relative humidity. /2/ Water transpired from one plant. /3/ Water evaporated from 36 sq in. free-water surface, under identical conditions.

Part III: TRANSPIRATION RATES, MULLEIN:

DIURNAL VARIATION

Period	Temp °C	Diffusion Pressure Deficit mm Hg	Sunlight %	Water Loss g/sq dm/hr ¹
1 1:00 AM	18.3	6.40		0.09
2 2:00	17.8	6.21		0.09
3 3:00	17.2	5.98		0.09
4 4:00	16.7	5.79		0.09
5 5:00	16.1	5.57		0.09
6 6:00	15.7	5.30	0	0.16
7 7:00	15.7	5.30	70	0.33
8 8:00	16.7	5.54	100	0.53
9 9:00	21.1	8.37	100	1.33
10 10:00	26.7	15.61	100	2.48
11 11:00	29.4	22.83	100	2.68
12 12:00	32.2	27.51	100	3.06
13 1:00 PM	33.9	31.48	100	2.80
14 2:00	35.0	34.26	100	2.42
15 3:00	33.9	31.48	100	1.65
16 4:00	32.2	28.22	10	1.60
17 5:00	29.4	22.83	0	0.68
18 6:00	25.6	14.63		0.13
19 7:00	23.3	9.56		0.13
20 8:00	22.2	7.55		0.13
21 9:00	22.2	7.35		0.13
22 10:00	21.7	7.13		0.13
23 11:00	21.1	6.88		0.13
24 12:00	21.1	6.88		0.13

/1/ g per sq dm leaf surface per hr.

Part IV: TRANSPIRATION RATES: GROWING SEASON

Species	Length of Season; Location	Water Loss L
1 Apple (Pyrus malus)	188 da; New York	8,200
2 Coconut (Cocos nucifera)	365 da; Philippines	19,000
3 Corn (Zea mays)	May 5-Sept 8; Kansas	245
4 Cowpea (Vigna sinensis)	May 19-Sept 2; Kansas	60
5 Date (Phoenix dactylifera)	365 da; Sahara Desert oasis	160,000
6 Potato (Solanum tuberosum)	Apr 18-July 30; Kansas	115
7 Ragweed (Ambrosia sp)	June 1-Aug 30	640
8 Sunflower (Helianthus annuus)	May 26-Aug 23; Kansas	560
9 Tomato (Lycopersicon esculentum)	May 19-Sept 2; Kansas	155
10 Wheat, winter (Triticum aestivum)	Oct 15-June 28; Kansas	115

Part V: TRANSPIRATION RATIO: SEASONAL VARIATION

Species	Seasonal Water Requirement							
	1912	1913	1914	1915	1916	1917	Av	
Colorado								
1 Alfalfa (Medicago sativa)	657	834	890	695	1047	822	824	
2 Amaranth (Amaranthus retroflexus)		320	306	229	340	307	300	
3 Barley (Hordeum vulgare)	443		501	404	664	522	507	
4 Corn (Zea mays)	280	399	368	253	495	346	357	
5 Cotton (Gossypium hirsutum)	488	657	574	443	612	522	549	
6 Cowpea (Vigna sinensis)		571	659	413	767	481	578	
7 Grama-grass (Bouteloua gracilis)			389	312	336	290	332	
8 Oat (Avena sativa)	449	617	615	445	809	636	595	
9 Rye (Secale cereale)			622	469	800	625	629	
10 Setaria (Setaria italica)	187	286	295	202	367	284	273	
11 Sorghum (Sorghum vulgare sudan.)			394	260	426	378	365	
12 Wheat, durum (Triticum aestivum)	394	496	518	405	636	471	487	
South Dakota								
13 Alfalfa (Medicago sativa)	735	735	1038	696	673	866	790	
14 Setaria (Setaria italica)	239	293	311	171	233	278	254	
15 Sorghum (Sorghum vulgare sudan.)				272	314	344	310	
16 Wheat, durum (Triticum aestivum)	463	436	528	333	352	487	433	

301. ION ABSORPTION AND ACCUMULATION: PLANTS

Parts I and II indicate the differential absorption among cations present in the culture solution. The accumulation ratio (Internal: external), shown in Parts I and III, is the ratio of concentration in cell sap to that in the external medium. Ratios greater than 1 indicate the movement of ions against a concentration gradient, i.e., from a region of lesser concentration to a region of greater concentration for each ion that accumulates. Part III reveals the influence of temperature on absorption by excised barley roots (*Hordeum vulgare*). Values were determined at end of 10 hours. Part IV shows the factors of time and distance from apex of excised barley roots on Rb absorption. Roots were placed in 0.005 M RbBr during the specific periods. Part V presents the course of ion absorption from 0.001 M $MnCl_2$ by root discs of beet (*Beta vulgaris*) as influenced by pretreatments. The root discs were washed at 25°C for 24 hr in distilled water (through which moist N_2 , O_2 , or air was passed) prior to transferring in the $MnCl_2$ solution. Because data have been greatly condensed, values should be considered with caution.

Part I: ION ABSORPTION AND ACCUMULATION: ALGAE

Ion	Chara ceratophylla			Nitella clavata			Valonia macrophyssa		
	Ion Concentration		Accumulation Ratio	Ion Concentration		Accumulation Ratio	Ion Concentration		Accumulation Ratio
	Cell Sap	Brackish Water		Cell Sap	Pond Water		Cell Sap	Sea Water	
	mole $\times 10^{-3}$			mole $\times 10^{-3}$			mole $\times 10^{-3}$		
1 Ca	5.3	1.8	2.9	10.2	0.8	12.8	1.7	12	0.1
2 Mg	15.5	6.5	2.4	17.7	1.7	10.4	Trace	57	
3 Na	140	60	2.3	10.0	0.2	50	90	500	0.2
4 K	88	1.4	63	54	0.05	1080	500	12	42
5 Cl	225	73	3.1	91	0.9	100	600	520	0.9
6 SO_4	3.9	2.8	1.4	8.3	0.3	28	Trace	36	

Part II: ION ABSORPTION AND ACCUMULATION: HIGHER PLANTS

Species	Cations Absorbed						Species	Cation Absorbed					
	Na	K	Mg	Ca	Sr	Total		Na	K	Mg	Ca	Sr	Total
	Equivalent	Percentages	Percentages	Percentages	Percentages	mEq/kg dry wt		Equivalent	Percentages	Percentages	Percentages	Percentages	mEq/kg dry wt
1 Buckwheat (<i>Fagopyrum esculentum</i>)	0.9	39	27	33	0.011	3230	8 Saltbush (<i>Atriplex litorale</i>)	10.7	56	23	10	0.006	4340
2 Corn (<i>Zea mays</i>)	2.9	70	16	11	0.005	2420	9 Spinach (<i>Spinacia oleracea</i>)	4.5	52	31	13	0.006	6520
3 Oat (<i>Avena sativa</i>)	3.7	73	14	8	0.004	2040	10 Sunflower (<i>Helianthus annuus</i>)	2.3	54	17	27	0.008	3020
4 Pea (<i>Pisum sativum</i>)	6.0	62	12	20	0.008	2140	11 Tobacco (<i>Nicotiana tabacum</i>)	4.0	51	24	21	0.006	4440
5 Plantain (<i>Plantago lanceolata</i>) ²	12.2	45	18	24	0.010	3690	12 Tomato (<i>Lycopersicon esculentum</i>)	4.1	44	25	27	0.010	4290
6 Plantain (<i>P. maritima</i>) ²	28	39	11	21		4370	13 Vetch (<i>Vicia sativa</i>)	10.6	44	19	26	0.011	2470
7 Saltbush (<i>Atriplex hortensis</i>)	19.7	39	31	10	0.004	4790	14 Culture solution	25	25	25	25	0.006	

/1/ The sum of equivalents of all fixed cations in 1 kg dry wt of plant tissue (cf Total) was determined and the amount of each cation expressed as percentage of this total. Analyses of entire plants (shoot and root), except as otherwise specified. /2/ Analyses of shoots.

Part III: EFFECT OF TEMPERATURE: BARLEY ROOTS

Temp °C	Ion Concentration						Accumulation Ratio		
	Culture Solution			Expressed Sap					
	K mEq/L	NO ₃ mEq/L	Br mEq/L	K mEq/L	NO ₃ mEq/L	Br mEq/L	K	NO ₃	Br
1 6	9.62	8.35	4.84	34.7	4.8	5.9	3.6	0.6	1.2
2 12	9.32	8.27	4.76	47.7	11.1	8.8	5.1	1.3	1.9
3 18	8.45	7.75	4.64	73.2	23.7	14.6	8.7	3.1	3.1
4 24	7.98	7.29	4.30	97.8	38.1	30.9	12.3	5.2	7.2
5 30	7.42	6.70	3.96	112	47.8	39.9	15.1	7.1	10.1

Part IV: EFFECT OF TIME AND DISTANCE: EXCISED BARLEY ROOTS

Values are mEq/kg fresh weight.

Distance from Apex cm	Root Weight ¹ mg	Rubidium Absorbed		Per Cent Gain 25-50 hr
		End of 25 hr mEq/kg	End of 50 hr mEq/kg	
1 to 1	33	32	44	38
2 1-2	38	26	34	29
3 2-3	39	25	27	8
4 3-4	38	24	26	8
5 4-5	40	24	25	6

/1/ Weight of 30 roots.

Part V: EFFECT OF PRETREATMENT: BEET ROOT DISCS

Values for manganese are followed, in parentheses, by those for chloride. Negative values indicate loss from the tissue to the bathing solution.

Values for manganese are followed, in parentheses, by those for chloride. Negative values indicate loss from the tissue to the bathing solution.											
Observation Period hr	Percentage Absorption of Mn and Cl				Observation Period hr	Percentage Absorption of Mn and Cl					
	Untreated	Pretreatment				Untreated	Pretreatment				
		Nitrogen	Oxygen	Air			Nitrogen	Oxygen	Air		
1	5	18.3(-2.0)	18.7(-0.2)	21.9(5.3)	19.1(2.3)	3	120	58.5(51.8)	76.2(60.1)	78.4(72.6)	79.6(74.6)
2	48	21.3(1.5)	27.9(16.2)	40.7(35.4)	32.9(27.3)	4	192	77.4(73.2)	84.3(79.1)	100(83.8)	100

302. TRANSLOCATION RATES: PLANTS

Values are linear rates of movement in phloem.

Substance	Species	Translocation Rate cm/hr	Method of Determination	Substance	Species	Translocation Rate cm/hr	Method of Determination
1 Virus	Sugar beet (<i>Beta vulgaris</i>)	150	Infectivity of tissue	11 Sugars	Oak (<i>Quercus robor</i>)	130-400	Conc. change
2 Curly top	Sugar beet (<i>B. vulgaris</i>)	7.5		12 Assimilates ²	Pumpkin, squash (<i>Cucurbita</i> spp)	55-160	Dry wt gain
3 Argentine	Dodder (<i>Cuscuta</i> sp), acropetal	10		13 Sucrose	Bean (<i>Phaseolus vulgaris</i>)	84	C ¹⁴ tracer
4 Curly top	Dodder (<i>Cuscuta</i> sp), basipetal	0		14 Sucrose	Soybean (<i>Glycine soja</i>)	84	C ¹⁴ tracer
5 Curly top	Tobacco (<i>Nicotiana tabacum</i>)	1.2		15 Indoleacetic acid	Cucumber (<i>Cucumis sativus</i>)	18.5	Auxin assay
6 Mosaic	Tobacco (<i>N. tabacum</i>)	17.8		16	Oat (<i>Avena sativa</i>)	1.0-1.2	
7 Streak	Corn (<i>Zea mays</i>)	20 ¹		17	Squash (<i>Cucurbita</i> sp)	20	
8	Various species	2-50	Observation of movement	18 2, 4-D	Alligator weed (<i>Alternanthera</i> sp)	4.2	Bending of stem
9 Fluorescein	Bryonia sp	50(15-65)		19	Bean (<i>Phaseolus vulgaris</i>)	10-100	
10	Geranium (<i>Pelargonium zonale</i>)	20-35		20 Iron		>43	Fe ⁵⁵ tracer
				21 Phosphate	Bean (<i>P. vulgaris</i>)	60(45-90)	P ³² tracer
				22 Sulfate		>41	S ³⁵ tracer

/1/ Minimum rate. /2/ Unspecified carbohydrates.

303. OSMOTIC RELATIONS: PLANT CELLS

Osmotic pressure (O.P.), a direct function of cell sap concentration, effects movement of water into roots and throughout the plant. Diffusion pressure gradients influencing translocation of solutes appear to arise primarily from osmotic differences between adjacent supplying and receiving cells. Diffusion pressure deficit (D.P.D.) = O.P. - T.P. (turgor pressure). Part I presents variation in leaves. Part II shows effect of specified factors. Part III gives seasonal values of shoots, plants grouped by depth of rooting. Part IV reveals changes with age of seedling, wheat (*Triticum aestivum*). Part V indicates values for tissues and organs. Parts VI and VII present diurnal and seasonal variations. Part VIII shows effect of soil water and soil nutrient contents on corn (*Zea mays*). Part IX specifies habitats, and Part X presents plant-group values. Values are atmospheres.

Part I: LEAVES VS O.P.

Species	O.P.	Species	O.P.
Herbaceous Plants		Trees	
1 Bedstraw (<i>Galium aparine</i>)	9.6	18 Ash (<i>Fraxinus americana</i>)	16.4
2 Beet (<i>Beta vulgaris</i>)	14	19 Birch (<i>Betula lutea</i>)	12.6-16.0
3 Bluegrass (<i>Poa pratensis</i>)	12.6-18.6	20 Cottonwood (<i>Populus deltoides</i>)	21.3
4 Burdock (<i>Arctium minus</i>)	9.8-13.7	21 Dogwood (<i>Cornus florida</i>)	11.1-16.7
5 Cattail (<i>Typha latifolia</i>)	9.7-11.8	22 Lemon (<i>Citrus limonia</i>)	15.1-21.4
6 Cinnamon fern (<i>Osmunda cinnamomea</i>)	9.8	23 Locust (<i>Robinia pseudoacacia</i>)	9.8-14.3
7 Cocklebur (<i>Xanthium</i> sp.)	8.4-10.7	24 Maple (<i>Acer rubrum</i>)	11.2-16.7
8 Cotton (<i>Gossypium</i> sp.)	22	25 Oak (<i>Quercus alba</i>)	15.8-18.4
9 Dandelion (<i>Taraxacum officinale</i>)	8.5-10.8	26 Oak (<i>Q. coccinea</i>)	19.1
10 Goldenrod (<i>Solidago</i> sp.)	10.3	27 Pine (<i>Pinus</i> spp.)	16.0-18.4
11 Iris (<i>Iris germanica</i>)	13.1	28 Poplar (<i>Populus alba</i>)	19.7-20.1
12 Lamb's-quarters (<i>Chenopodium album</i>)	13.2	29 Spruce (<i>Picea engelmannii</i>)	11.5-23.5
13 Mullein (<i>Verbascum thapsus</i>)	8.0-10.1	30 Sweetgum (<i>Liquidambar styraciflua</i>)	13.3-15.5
14 Pea (<i>Pisum sativum</i>)	9.2	31 Sycamore (<i>Platanus occidentalis</i>)	13.5
15 Pokeweed (<i>Phytolacca decandra</i>)	8.5-9.5	32 Walnut (<i>Juglans nigra</i>)	12.6-18.3
16 Sunflower (<i>Helianthus annuus</i>)	13.8-18.0	33 Willow (<i>Salix alba</i>)	12.3-14.2
17 Touch-me-not (<i>Impatiens biflora</i>)	4.6-8.4	34 Yellow-poplar (<i>Liriodendron tulipifera</i>)	11.3-16.4

Part III: SHOOTS VS O.P.

Species	Osmotic Pressure									
	Apr 19	Apr 24	May 8	May 28	Jun 8	Jun 20	Jul 2	Jul 9	Jul 31	
Shallow-rooted Plants										
1 June grass (<i>Koeleria cristata</i>)	16.4	17.4	24.1	35						
2 Lomatium (<i>Lomatium foeniculacum</i>)	11.5	14.6	16.1	20.2						
3 Milk vetch (<i>Astragalus crassicastris</i>)	10.9	13.2	15.4	18.7						
Relatively Deep-rooted Plants										
4 Bluestem (<i>Andropogon scoparius</i>)	8.1	9.6	9.9	25.3	18.1	17.4	31.3			
5 Goldenrod (<i>Solidago glaberrima</i>)		12.0		12.8	14.3	16.8				
6 Sunflower (<i>Helianthus rigidus</i>)			12.6	19.9	15.2	22.9	36.9			
Deep-rooted Plants										
7 False-indigo (<i>Baptisia leucophaea</i>)	8.6	10.8	12.0	14.8	16.0	16.7	17.3			
8 Lead plant (<i>Amorpha canescens</i>)		11.6	13.1	20.8	16.2	15.1	17.2	20	22.1	
9 Scurf pea (<i>Psoralea tenuiflora</i>)		12.2	14.2	17.8	16.0	16.8	15.2	17.2	15.8	

Part V: TISSUE-ORGAN VS O.P., D.P.D.

Tissue-Organ		O.P.			Tissue-Organ		D.P.D.	Tissue-Organ		D.P.D.
		Beech ¹	Hellebore ²	Nettle ³						
Leaf					Root, absorption zone			Petiole		
1 Epidermis	15	19.2	18.8		10 Epidermis	0.7		18 Stem, 225 cm high	5.0	
2 Spongy parenchyma	22.4	22.5	24.7		11 Cortex			20 Stem, 35 cm high	2.9	
3 Palisade parenchyma	37.7	32.9	37.7		12 1st row	1.4		21 Root, older portion	2.4	
Stem					13 3rd row	1.5		22 Root, absorption zone	1.6	
4 Cambium	24.6	21.9	21.5		14 4th row	2.1		O.P.		
5 Xylem parenchyma	36.6	22.2	23		15 5th row	2.8		23 Sieve-tubes	15.6-17.1	
6 Pith		20.6	18.7		16 6th row	3.0		24 Stem wood	7.5-11.8	
7 Wood rays	35.2				17 Endodermis	1.7		25 Root wood	6.3	
8 Cortex	26.1	20.8	19.2		17 Wood parenchyma	0.9		26 Stem cambium	11.1-12.9	
9 Phloem parenchyma	22.5		20.4					27 Root cambium	9.7-11.0	

/1/ *Fagus* sp. /2/ *Helleborus* sp. /3/ *Urtica* sp.

Part VI: TIME OF DAY VS O.P.

Species		O.P.; (D.P.D.)				
		6 AM	10 AM	2 PM	5 PM	8 PM
King-weed (<i>Ambrosia trifida</i>)						
1 Top leaf	12.5;(7.5)	15.3;(15)	17.4;(17.5)	16.5;(15)	16.3;(15)	
2 1st leaf from top	12.5	15.6	17.2	15.7	14.9	
3 2nd leaf from top	12.9;(8)	15;(14.5)	17.1;(17)	15.7	14.9;(15)	
4 Lowest leaf	10.1;(6.5)	13;(13.5)	15.9;(15.5)	14.3	14;(14)	
Dock (<i>Rumex patientia</i>)						
5 Guard cell		16.6	21	20.2	13.2	
6 Subsidiary cell		16.6	16.6	17.8	15.5	
7 Epidermal cell		14.4	14.4	14.4	13.2	
Bluestem (<i>Andropogon scoparius</i>)						
8 Shoots (extreme drought)		12 N	2 PM	4 PM	6 PM	8 PM
		23	25	27	26	21.5
						20.5
						21
						25

Part VIII: SOIL MOISTURE-SOLUTES VS O.P.

Soil Water, g/100g		Corn Plant	
		Shoots	Roots
		O.P.	O.P.
1 31	22.1	5.9	
2 16	24.4	7.8	
3 14	25.0	9.2	
4 11	26.5	12.0	
Soil Solution, O.P.			
5 1.2	6.2	4.6	
6 2.0	7.1	5.5	
7 3.4	7.0	6.6	
8 5.0	7.2	7.5	
9 7.2	7.3	8.2	

Part IX: HABITAT VS O.P.

Habitat		Woody Plants	Herbaceous Plants
		O.P.	O.P.
Jamaica			
1 Ruinate	13	10	
2 Ridge forest	12	9	
3 Leeward ravines	11	8	
4 Windward	10	8	
Arizona			
5 Rocky slopes	22	16	
6 Canyons	21	13	
7 Arroyos	17	13	
8 Bajada slopes	30	20	
9 Salt spots	45	24	

Part VII: SEASON VS O.P.

Species		Osmotic Pressure						
		Oct	Dec	Jan	Feb	Mar	Apr	June
Aspen (<i>Populus tremuloides</i>)								
1 Aspen	15	16.8	16.2	13.7	17			10.6
Spruce (<i>Picea glauca</i>)								
2 Spruce	17.1	20.3	20		24.9	20.1	21	19.7
Twin-flower (<i>Linnaea borealis</i>)								
3 Twin-flower	19.6	25			25.6			14.3
Wintergreen (<i>Pyrola rotundifolia</i>)								
4 Wintergreen		24.6			23.9		17.2	12.6

Part X: PLANT GROUPS VS O.P.

Plant Group		O.P.
1 Summer ephemerals	8-42	
2 Succulents and winter ephemerals	4-24	
3 Xerophytes	14-57	
4 Hydrophytes	8-13	
5 Air leaves	18-21	
6 Water leaves	8-9	
7 Epiphytes	3-6	
8 Halophytes	30-115	
9 Parasites ¹	14-17	
10 Hosts	11-14	

/1/ As for example, mistletoe (*Phoradendron flavens*), 15.8; host, 11.6.

304. OSMOTIC REGULATION: ANIMALS

Organism	Osmotic Characteristics	Regulatory Mechanisms
1 Marine invertebrate eggs; Phascolosoma	Osmotic adjustment	No volume regulation known.
2 Marine mollusks; maja; Nereis pelagica; N. cultrifera		Volume regulation.
3 N. diversicolor	Limited osmoregulation	Low permeability; salt reabsorption in nephridia.
4 Gunda		Water storage.
5 Carcinus	Fair osmoregulation in hypotonic media	Selective absorption of salts from medium; kidney reabsorption or secretion; low permeability.
6 Uca	Regulation in hypertonic and hypotonic media except at extremes	Unknown.
7 Crayfish; fresh-water teleosts; amphibia	Unlimited (?) regulation in hypotonic media	Hypotonic copious urine; salt reabsorption or water secretion; low surface permeability.
8 Fresh-water embryos		Water impermeability in some.
9 Elasmobranchs	Maintenance of hypertonicity in both media	Urea retention.
10 Some marine teleosts	Regulation in hypertonic media	Extrarenal salt excretion; low water intake.
11 Artemia	Regulation in moist air	Unknown.
12 Earthworm; amphibians		Low skin permeability; salt absorption from medium; salt reabsorption in kidney.
13 Insects	Regulation in dry air	Impermeable cuticle; hypertonic urine.
14 Birds, reptiles, mammals		Hypertonic urine; water reabsorption in kidney.

305. WATER BALANCE: ANIMALS

Part I: TERRESTRIAL ANIMALS

Values are for the resting state. Body weight values are g; others are g/100g body weight per day.

Animal	Body Weight g	Water Turnover	Water Intake ¹	Metabolic Water ²	Output	
					Urine	Other ³
1 Man	65,000	4.0	3.5	0.5	1.9	2.1
2 Cat	2,900	8.4	7.2	1.2	4.1	4.3
Cattle						
3 Brahman, dry	409,000	6.1	5.5	0.6		
4 Holstein, dry	745,000	6.7	6.0	0.7		
5 Holstein, milking	529,000	15.9	14.8	1.1		
6 Jersey, milking	403,000	12.8	11.8	1.0		
7 Steer	584,000	4.8	4.0	0.8	0.9	3.9
8 Dog	18,600	6.0	4.6	1.4	1.9	4.1
9 Elephant	3,670,000	4.6	4.2	0.4	1.3	3.3
10 Guinea pig	450	17.0	14.5	2.5		
11 Hamster, golden	70	21.6	18.4	3.2		
12 Horse	420,000	6.2	5.5	0.7	1.2	4.3
13 Monkey, rhesus	4,900	8.2	7.0	1.2	5.3	2.9
14 Mouse, albino	21	20.4	10.1	10.3	4.3	16.1
15 Mouse, deer	20	15.4	9.0	6.4		
16 Rabbit	3,670	13.0	11.3	1.7	7.4 ⁴	5.6
17 Rat, albino	225	16.3	13.9	2.4	5.8 ⁴	10.5
18 Rat, cotton	130		17.7			
19 Rat, kangaroo	106	8.2	5.5	2.7		
20 Vole	29	27.3	21.1	6.2		
21 Chicken	1,550	16.1	13.0	3.1		

/1/ In drink and food. /2/ Water of oxidation of foods or body protoplasm. /3/ Water lost in sweat, respiratory tract, feces, and incorporation into new protoplasm. /4/ A value of 3.8 has been reported.

Part II: AQUATIC ANIMALS

Values are for the resting state. Body volume values are ml and those for water turnover are per cent body volume per day at the indicated temperature.

Animal	Body Volume ml	Water Turnover % body/day	Temp °C	Animal	Body Volume ml	Water Turnover % body/day	Temp °C
In Fresh Water				In Sea Water			
1 Amphibia				15 Protozoa (concluded)			
2 Bufo vulgaris	22	117		16 Euplotes	3x10 ⁻⁷	10 ⁴	25
3 Rana esculenta	65	22		17 Lembus	2x10 ⁻⁹	6x10 ⁴	26
4 Rana pipiens	32	40	20	18 Leucophrys	4.7x10 ⁻⁷	3,300	21
5 Rana temporaria	9	100		19 Paramesidium	1.9x10 ⁻⁷	6,200	22
6 Salamandra	20	53		20 Rhabdostyla	8x10 ⁻⁹	1.1x10 ⁴	15
7 Triton marmoratus	5	43		21 Spirostomum	2.2x10 ⁻⁶	550	
Insecta				22 Zoöthamnium	1.4x10 ⁻⁸	5,500	15
8 Chironomus larva	0.1	22		In Sea Water			
9 Corethra larva	6.2	19	20	22 Pisces			
10 Crustacea				23 Anguilla	250	6.5	
11 Cambarus	13	5.3		24 Myoxocephalus	180	11.5	
12 Eriocheir	60	3.6	13	25 Crustacea			
13 Potamobius	46	4.1		26 Cancer	300	6.5	
14 Annelida				27 Carcinus	40	10.0	
15 Lumbricus	4	60	19	28 Maia	2,200	2.7	
16 Protozoa				29 Protozoa			
17 Amoeba proteus	3x10 ⁻⁶	360	23	27 Amoeba mira	6x10 ⁻⁹	4,300	
18 Cyclidium	2x10 ⁻⁹	2.2x10 ⁴		28 Cothurnia	1.2x10 ⁻⁸	700	15
				29 Zoöthamnium marinum	1.2x10 ⁻⁷	750	15

306. BODY WATER AND PLASMA VOLUME: MAMMALS

Values in parentheses are ranges and unless followed by superscript, are estimate "b" of the 95% range (cf Introduction). * = range is only an estimate from comparable data in other animals.

Animal	Total Body Water			Extracellular Body Water			Plasma Volume ¹	
	Specifications	ml/kg	Method ²	Specifications	ml/kg	Method ²	Specifications	ml/kg
Man	Fetus, <100g	914(871-957)	Des	Infant, premature	435(300-570)	Na ²⁴		
	100-499g	882(837-927)	Des					
	500-999g	852(792-912)	Des	Infant, full term	391(275-510)	Na ²⁴		
	1000-1499g	832(798-866)	Des		346(275-419) ^d	Inulin ³	<1 yr	47.7(34.0-61.4)
	1500-2499g	783(710-856)	Des		353(297-414) ^d	Ferrocyanide ³		
	Newborn	757(703-811)	D ₂ O	<1 mo	412(354-470)	Thio		
	1-12 mo	626(509-745)	D ₂ O	1-12 mo	364(268-460)	Thio		
	1-10 yr	589(548-630)	D ₂ O	1-6 yr	309(236-382)	Thio	1-9 yr	46.9(34.8-59.0)
	10-16 yr ♂	590(516-664)	D ₂ O	10-18 yr ♂	286(228-344)	Thio	10-18 yr ♂	49.0(37.0-61.0)
	♀	561(489-633)	D ₂ O				♀	42.6(30.0-55.2)
	Adult ♂	635	Des	Adult ♂	248(188-308)	Thio	Adult ♂	46.2(33.7-58.7)
	♂	592(472-712)	D ₂ O	♂♀	158(131-185)	Inulin ³		
	♂	542(426-658)	AP	♂♀	178(143-213)	Sucrose ³		
	♂	532(462-602)	T ₂ O	♂♀	159(141-189) ^d	Mannitol ³		
	♂ <70kg	626(517-735)	D ₂ O	♂ <60kg	248(154-342)	Thio		
	♂ >70kg	560(470-650)	D ₂ O	♂ 60-69kg	249(196-302)	Thio	♂ 18-29 yr	46.0(34.7-57.3)
	♂ 17-39 yr	602(502-702)	D ₂ O	♂ 70-79kg	241(176-306)	Thio	♂ 30-49 yr	43.8(31.8-55.8)
	♂ 40-59 yr	572(471-673)	D ₂ O	♂ >80kg	221(182-260)	Thio	♂ 50-69 yr	46.0(30.6-61.4)
	♂ >60 yr	541(478-628) ^d	D ₂ O	♂ 20-60+ yr	260(220-290) ^c	Cl ³⁸	♂ >70 yr	48.7(35.3-62.1)
	♀	560	Des	♀	208(144-272)	Thio	♀	43.5(32.5-54.5)
	♀	496(404-588)	D ₂ O	♀ 40-70+ kg	245(185-305)	Bromide		
	♀	448(336-556)	AP					
	♀ <60kg	505(415-595)	D ₂ O	♀ <50kg	220(160-280)	Thio		
	♀ >60kg	486(395-577)	D ₂ O	♀ 50-69kg	198(138-258)	Thio		
	♀ <40 yr	511(430-592)	D ₂ O	♀ >70kg	183	Thio		
	♀ 40 yr	468(389-547)	D ₂ O	Pregnant, 1st 1/3	281(196-366)	Thio		
	♀ 20-39 yr	444	AP	2nd 1/3	284(221-347)	Thio		
	♀ 40-59 yr	446	AP	3rd 1/3	303(233-373)	Thio		
	♀ 60-79 yr	422	AP	60-69kg	310(250-370)	Thio		
	♀ >80 yr	488	AP	80-89kg	278(227-329)	Thio		
	Pregnant, 2nd 1/3	547(485-600)	D ₂ O	>100kg	241(191-291)	Thio	Pregnant ⁴	50.7(36.0-76.8)
	3rd 1/3	544(485-590)	D ₂ O					
	Post-partum	520(435-580)	D ₂ O					
Cat	Newborn	807	Des					
	2 wk	738	Des					
	12 wk	666	Des					
	Adult	580	Des	Adult	288	Thio	Adult	46.4(32.2-56.4)
Cattle	Fattened	539(431-647)	AP				Adult	38.8(36.0-41.6)
	Newborn	779(737-803) ^d	Des	Adult	299(240-360) ^d	Na ²⁴		
	Young	700(670-730)	Des		312(290-340) ^c	Cl ³⁶		
	Adult, lean	700(619-756) ^d	Des		320(239-408)	Thio	Adult	52.7(35.0-70.4)
Dog	obese	596(503-690)	Des		198(145-251)	Inulin ³		
	unspecified	628(550-662) ^d	Des		216(166-214)	Mannitol ³		
	18.6kg	717	AP					
	44.2kg	706	AP					
Goat	Fetus <12g	894(863-966) ^d	Des					
	71-112g	716(684-754) ^d	Des					
	Newborn	710	Des					
	Adult	635(524-746)	Des				Adult	43.0
Monkey		691(650-720) ^d	Des	Adult	208(121-195)	Thio	Adult	44.9(27.1-62.7)
Mouse	Fetus, 1/2 time	871	Des					
	Newborn	833	Des					
	15 da	757	Des					
	30 da	766	Des				Adult	57.4
Rabbit	Fetus, <1g	915(914-915) ^d	Des					
	>50g	816(815-818) ^d	Des					
	Newborn	830(772-888)*	Des					
	Young	720(651-767) ^d	Des					
Rat	Adult 2.7-4.0kg	667(550-785)	AP	Adult 2.7-4.0kg	246(200-295)	Thio	Adult 2.7-4.0kg	38.0(27-48)
	Fetus, <0.20g	922(918-926)	Des					
	0.5-1.0g	900(892-908)	Des					
	2.5-5.0g	874(867-881)	Des					
	Newborn	868(851-885)*	Des					
	6 da	814(773-855)	Des					
	10-15 da	757(719-795)	Des				Very young	54.7(49.6-59.8)
	1-2 mo	697(662-732)*	Des					
	2-3 mo	684(643-725)*	Des				Pubescent	65.0(59.2-70.8)
	Adult, lean ♂	690(676-704)*	Des	Adult	300(260-340)	Thio	Adult	41.5(29.5-53.5)
	♀	684(670-698)*	Des					
	average ♂	660(620-700)*	Des					
	♀	650(610-690)*	Des					
	obese ♂	558(508-608)*	Des					
	♀	586(516-656)*	Des					
	♂ 250-390g	674(505-840)	AP	♂ 290-350g	269(190-350)	Thio	♂ 290-350g	45.1(31-59)
Swine	Newborn	834	Des					
	17 da	799(796-802) ^d	Des					

/1/ Measured by the dye method using T-1824 (Evans blue). /2/ AP = antipyrine; Cl³⁶, Cl³⁸ = radioactive isotopes of chlorine; Des = desiccation; D₂O = deuterium oxide; Ferrocyanide = ferrocyanide; Na²⁴ = radioactive isotope of sodium; Thio = thiocyanate; T₂O = tritium oxide. /3/ Constant infusion technique. /4/ Third trimester. /5/ Measured by radio-iodinated albumin.

307. KIDNEY FUNCTION: MAMMALS

Values in parentheses are ranges and, unless accompanied by superscript, are estimate "b" of the 95% range (cf Introduction).

Species	Age Group	ERPF ¹		ERPF ²		Glom. Filtration Rate ³		Filtration Fraction ⁴	Maximum Rate of Tubular Transfer (Tm)			Clearances ⁵	
		ml/min	ml/min per sq m S.A. ⁸	ml/min	ml/min per sq m S.A. ⁸	ml/min	ml/min per sq m S.A. ⁸		p-Aminohippurate	Diodrast	Glucose	Urea ⁶	Creatinine ⁷
									mg/min per sq m S.A. ⁸			ml/min per sq m S.A. ⁸	
1 Man	Infant												
2	Premature, 4-28 da			149		45(26-64)	34	12.9			77	32(20-43)	
3	Full term, 2-8 da			73		38(17-60)	49	16(6-26)				23.2	
4	10-22 da			229		50(32-69)	24	21.4				36	53.4(36-71)
5	1-5 mo			326		77(39-114)	24	51				55(23-88)	
6	6-11 mo			480		103(49-157)	22(8-36)	50				68	
7	12-19 mo			519(419-619)		127(62-191)	25(15-35)	61(19-104)				71	
8	Children, 2-12 yr			654(533-775)		127(89-164)	20(12-28)	74(36-112)			543(285-828)	75(38-112)	
9	Adult ⁹	1166		655(544-761) ^C		127(117-140) ^C	19(11-27)	80(46-113)	51.8(34-69)			75(59-95)	139(115-192)
10	Adult ⁹	940		600(518-669) ^C		118(109-127) ^C	20(14-26)	77(56-99)	42.6(24-62)		303(248-358)	75(59-95)	148(117-181)
11	Pregnancy, 2-8 mo near term	1359(964-1799)		727(590-865)		170(147-193)	22		45.6			104(86-122)	186(102-317)
12	Dog	300 ¹⁰	480	561(461-570)		126(69-183)	19.5					79(50-108)	153(120-231)
13	Rabbit	78	430	265(135-400)	53	84(45-120)	32(26-38)	19	20(13-48) ^C		300(170-390) ^C	56(28-83)	
14	Rat	8	221	300(180-410)	9.2	50(30-70)	17		33(30-37)		79(55-105)	25.5	
				4.4	145	40(23-96)	28	20	9.3			10.9(5-17)	

/1/ Effective Renal Blood Flow calculated from Effective Renal Plasma Flow \div 1 minus hematocrit. /2/ Effective Renal Plasma Flow measured by PAH(p-aminohippurate) or diodrast clearance. Values require upward correction of about 10% for incomplete extraction by kidney to yield values for total renal plasma flow. /3/ Glomerular filtration rate (GFR) measured for man by inulin or mannitol; for dog, rabbit, and rat, by inulin, mannitol or creatinine. /4/ GFR/ERPF (% of plasma filtered). /5/ Minimum volume of blood required to furnish the amount of substance excreted in urine in one minute. /6/ Maximum whole blood clearance, or when urine flow rate is 2 ml or more per minute. Urea concentration in urine \times urine flow \div urea concentration in blood. /7/ Exogenous. /8/ In clinical medicine, values are usually based on body surface area of 1.73 sq m (adult, 70 kg σ , 60 kg η), whereas for other animals values are per sq m; in this table, values are based on dog 13 kg, 0.623 sq m; rabbit 3 kg, 0.18 sq m; rat 0.2 kg, 0.03 sq m. /9/ Unanesthetized. /10/ Hematocrit = 0.45.

308. KIDNEY CONCENTRATING POWER AND ELECTROLYTE EXCRETION: MAMMALS

Values in parentheses are ranges, estimate "c" of the 95% range (cf Introduction).

Species	Urine Output ml/kg/da	Max. Conc.		Maximum Specific Gravity ³	Max. U/P Osmotic Gradient ⁴	Chloride		Bicarbonate ¹		Phosphate		Sulfate	
		Urea mOs/L ²	Osmolar mOs/L ²			Excretion mEq/da	Conc. mEq/L	Excretion mEq/da	Conc. mEq/L	Excretion mEq/da	Conc. mEq/L	Excretion mEq/da	Conc. mEq/L
1 Man	(9-29)	1000	(1200-1400)	1.040	4.2	118(58-250)	110(49-210)	1.5(0-36)	1.1(0-26)	36(22-54) ⁵	28(0-120)	37(11-56)	26(13-56)
2 Cat	26(22-30)					282(127-610)				22			
3 Cow	14					40(0-222)	76(0-400)	18(0.01-71)	39(0-150)	7(0-38)	(0-120)	26(1-48)	48(6-800)
4 Dog	31(25-41)	1600	(1700-3000)	1.060	5.5-10	3.6(0.8-9.8)	41(3.4-94)			1.4(0.6-2.1)	4.6(1.5-6.9)		
5 Rabbit	90(20-300)					1.3(0.4-1.9)	96(31-144)			0.5(0.27-0.55)		0.17(0.13-0.21)	5.5
6 Rat	43(24-77)	2400	2400	1.056	8.2								

Species	Sodium		Potassium		Ammonia		Calcium		Magnesium		Water
	Excretion mEq/da	Conc. mEq/L	Excretion mEq/da	Conc. mEq/L	Excretion mEq/da	Conc. mEq/L	Excretion mEq/da	Conc. mEq/L	Excretion mEq/da	Conc. mEq/L	Excretion ml/da
7 Man	120(40-186)	114(35-167)	64(53-91)	50(27-150)	38(30-70)	27(20-50)	8(2-18)	7.5(1.4-13)	9(6-16)	8.2(5.8-11.6)	1400(500-3000)
8 Cat							0.11	3.0	0.4	11.9	36
9 Cow	360(89-475)		2370(1650-2980)				18.0(4.5-74.3)		339(154-578)		
10 Dog	32(1-209)	74(2-530)	31(3-128)	84(18-540)	25(2.9-82)	69(4-190)	1.3(0.1-7.0)	2.1(0.2-7.6)	3.9(0.7-20.7)	8.3(2.8-26.9)	420(122-2000)
11 Rabbit	60						1.7(0.5-3.4)	5.2(1.6-11.4)	2.7	8.5	258(34-935)
12 Rat	1.4(0.2-1.9)	90(35-164)	0.9(0.4-1.9)	118(37-188)	0.7		0.09(0.02-0.16)		0.17(0.04-0.3)		12(4.3-24)

/1/ Bicarbonate excretion is a function of urine pH. For man little is excreted at pH 5.2; 1.5 mEq at 6.0; 6 mEq at 6.6; 14 mEq at 7.0; 36 mEq at 7.4. /2/ Milliosmols per liter. /3/ Specific gravity during imposed thirst (water deprivation for 12 or 24 hours) is a measure of kidney concentrating power used in clinical medicine. /4/ Ratio of osmolar concentrations of solutes in urine and plasma. /5/ Base equivalence assumed as 1.0. Proportion of BH_2PO_4 to B_2HPO_4 varies with pH of urine. At pH 5.4, proportion is 0.96 to 0.04, and the base equivalence is 1.04. At pH of plasma, the proportion is 0.2 to 0.8, and the equivalence is 1.8.

309. GASTRIC SECRETION, TESTS: MAN

Values in parentheses are ranges, and, unless followed by superscript, are estimate "d" of the 95% range (cf Introduction).

Condition	Age Group	Volume ml/hr	Free HCl mEq/liter ¹	Total HCl mEq/liter ¹	pH	Pepsin units/ml ²	Mucin mg/100 ml
Fasting	Adult, 20-39 yr, ♂	77 (0-164)	32 (0-95)				
	♀	70 (0-160)	24 (0-74)				
	40-59 yr, ♂	84 (0-176)	30 (0-87)	66 (13-118) ³	σ♀ (2.2-2.7) ^{3, 4}	σ♀ 65 (0-162) ³	σ♀ 181 (11-351) ³
	♀	66 (0-155)	17 (0-74)	43 (5-70) ³			
	60-79 yr, ♂	65 (0-149)	16 (0-60)				
Basal, one hour	♀	48 (0-103)	10 (0-32)				
	Adult, 20-59 yr, ♂	79 (0-176)	26 (0-95)				
Nocturnal	♀	65 (0-160)	20 (0-74)				
	Adult ³ ♂	54 (14-99)	30 (1-90)		σ♀ (1.1-2.6)	σ♀ 205 ⁵	
After test meal	♀	38 (12-75)	27 (3-72)				
	Adult, 20-39 yr, ♂	114 (13-217)	47 (13-80)	62 (29-96)			
	♀	99 (20-178)	33 (4-61)	50 (21-80)			
	40-59 yr, ♂	99 (13-192)	44 (6-79)	58 (19-96)	(1.6-1.8) ³	σ♀ 7 (3-15) ^{3, 6}	
	♀	93 (16-172)	33 (4-62)	50 (20-80)			
After histamine	60-79 yr, ♂	91 (0-192)	36 (0-76)	52 (17-91)			
	♀	82 (13-156)	33 (1-65)	50 (16-85)			
	Children, 6-11 mo, ♂♀	18 (6-54) ^c	(0-50) ^c	(8-110) ^c	(1.3-1.5)		
	1-15 yr, ♂♀	50 (6-180) ^c	(15-115) ^c	(26-145) ^c	(1.2-2)		
	Adult, 20-39 yr, ♂	131 (6-256)	76 (11-142)				
After insulin	♀	99 (2-203)	62 (0-126)				
	40-59 yr, ♂	137 (0-283)	69 (0-156)			32 ³	σ♀ 136 (0-330) ³
	♀	101 (0-229)	53 (0-125)			43 ³	
	60-79 yr, ♂	108 (0-257)	44 (0-130)				
	♀	84 (0-195)	45 (0-113)				
After insulin	Adult ³ ♂	140 (85-204)	123 (103-140)	128 (111-144)	σ♀ (1.2-1.8)	58	σ♀ 225 (83-367)
	♀	109 (70-176)	123 (105-133)	128 (112-138)			

/1/ One mEq/liter is the same as one "clinical unit" or one "degree of acidity" = ml of 0.1 N NaOH required to neutralize 100 ml of gastric secretion. /2/ Unless otherwise indicated, "units" refer to proteolytic units in the Anson and Mirsky method. /3/ Age not specified. /4/ Range of means. The range for one normal person may be 1.5-5.0. /5/ Micrograms per ml (refers to equivalent activity of a standard pepsin). /6/ mg/ml (refers to equivalence to a standard pepsin).

310. LIVER FUNCTION, TESTS: MAN

Values in parentheses are ranges, estimate "d" of the 95% range (cf Introduction).

Test or Constituent	Method	Normal Values	Abnormal Levels
Tests Related to Bilirubin Metabolism			
1 Serum bilirubin, total	Van den Bergh	<0.2 mg/100 ml	Increased
2 Serum bilirubin, total	Photoelectric	0.25-1.5 mg/100 ml	Increased
3 Serum bilirubin, direct	Photoelectric	0-1.5 mg/100 ml	Increased
4 Icterus index	Acetone	1-5 units	Increased
5 Bilirubin clearance	I.V. injection	<5% retention at 4 hr	>5% retention
6 Urobilinogen, urine	Quantitative	<4 mg in 24 hr	Increased ¹
7 Urobilinogen, urine	Simplified quantitative	<1.9 "Ehrlich units" in 2 hr	Increased ¹
8 Urobilinogen, fecal	Quantitative	40-280 mg in 24 hr	Increased; decreased ²
Dye Excretion Tests			
9 Bromsulfalein	Photoelectric; dose 5 mg/kg	<6% at 45 min	>6%
10 Rose Bengal	Spectroscopic	<55% at 8 min	>55%
Tests Related to Carbohydrate Metabolism			
11 Galactose tolerance	Urine, after oral administration	<3 g in 5 hr	>3 g ³
12 Galactose tolerance	Blood, after I.V. administration	0 at 75 min	Positive ³
13 Levulose tolerance	Blood, after I.V. administration	<20 mg at 1 hr	>20 mg
14 Lactic acid tolerance	Blood, after I.V. administration	<5 mg at 30 min	>5 mg
Tests Related to Protein Metabolism			
15 Serum albumin	Sodium sulfate	4.89 (3.6-5.6) g/100 ml	Decreased
16 Serum globulin	Sodium sulfate	2.12 (2.0-3.7) g/100 ml	Increased
17 Albumin/globulin	Sodium sulfate	2.31 (1.5-2.5) g/100 ml	Decreased
18 Zinc turbidity	Zinc sulfate	6-12.5 units	>12.5 units
19 Prothrombin	Quick	70-100% of normal control	Decreased
20 Prothrombin response	Response to vitamin K	>10% rise in prothrombin	<10% rise
21 Cephalin flocculation ⁴	Hanger	<2+, 24 hr; up to 2+, 48 hr	3-4+, 48 hr
22 Thymol turbidity	MacLagan	<5 units at 30 min	>5 units
23 Thymol flocculation	Neefe	0-1 plus at 18 hr	2+ or more
24 Colloidal Red	Ducci	0-1 plus at 24 hr	>2+
25 Takata-ara		No flocculation	Flocculation
Tests Related to Lipid Metabolism			
26 Cholesterol, total	Chemical	194-235 mg/100 ml	Increased ²
27 Cholesterol, esterified	Chemical	70-75% of total cholesterol	<50% total cholesterol
28 Phospholipid	Chemical	145-280 mg/100 ml	Increased; decreased ³
29 Lipids, total	Chemical	591-720 mg/100 ml	Increased; decreased ³
Miscellaneous Tests			
30 Serum alkaline phosphatase	Bodansky	1-4 units	>4 units ²
31 Serum cholinesterase	Potentiometric (Michel)	0.66-1.06	Decreased
32 Hippuric acid	Sodium benzoate; 3 g, oral	2.5-3.5 g in urine after 4 hr	Decreased

/1/ In liver disease and hemolytic states. /2/ In complete obstruction of biliary passages. /3/ Parenchymal liver damage. /4/ Cephalin cholesterol.

311. BODY TEMPERATURES

Part I: MAMMALS

Temperatures are daytime rectal or cloacal averages.

Species		Temperature, °C	Species		Temperature, °C
1	Man (<i>Homo sapiens</i>)	36.9(36.2-37.6)	84	Jackal (<i>Canis aureus indicus</i>)	38.3
2	Agouti (<i>Dasyprocta acouchy</i>)	38.9(38.7-39.0)	85	Kangaroo, red (<i>Macropus rufus</i>)	35.8(35.0-36.8)
3	Agouti (<i>D. aguti</i>)	38.5(37.9-39.0)	86	Kangaroo, great gray (<i>M. major</i>)	36.0(34.7-36.0)
4	Agouti (<i>D. azare</i>)	39.0(38.9-39.1)	87	Kinkajou (<i>Potos caudivolvulus</i>)	36.8(36.4-37.2)
5	Agouti (<i>D. prymnolopha</i>)	38.9(37.9-39.0)	88	Koala (<i>Phascolarctos cinereus</i>)	36.4(34.9-38.4)
6	Anteater, three-toed (<i>Tamandua tetradactyla</i>)	33.8(32.0-35.2)	89	Lemming, collared (<i>Dicrostonyx rubricatus</i>)	38.3(35.4-41.2)
7	Anteater, two-toed (<i>Cyclopes sp.</i>)	30.7(30.2-31.1)	90	Lemur (<i>Lemur variegatus</i>)	38.2(37.5-38.9)
8	Ape (<i>Cynopithecus niger</i>)	37.9(37.1-38.8)	91	Loris (<i>Perodicticus potto</i>)	36.9(34.9-38.9)
9	Armadillo (<i>Dasyurus citellus</i>)	31.3(30.0-32.5)	92	Macaque (<i>Macaca macacus</i>)	38.4(36.4-40.0)
10	Armadillo (<i>D. novemcinctus</i>)	32.5(30.0-32.5)	93	Manatee (<i>Trichechus manatus</i>)	39.5 ²
11	Armadillo (<i>D. sexcinctus</i>)	33.2(32.2-35.0)	94	Marmot (<i>Actomys marmota</i>)	34.2(31.2-37.2)
12	Armadillo (<i>D. villosus</i>)	33.4(31.8-35.0)	95	Marmot (<i>Marmota marmota</i>)	36.2(31.2-39.0)
13	Ass (<i>Equus asinus taeniopus</i>)	37.4(37.0-37.8)	96	Marmot, hoary (<i>M. caligata</i>)	36.4(33.5-39.3)
14	Baboon (<i>Papio hamadryas</i>)	38.1(37.3-38.7)	97	Mole, common (<i>Scalopus aquaticus</i>)	35.8(34.6-37.0)
15	Bat (<i>Eptesicus fuscus</i>)	38.1(36.2-40.0)	98	Monkey (<i>Macaca mulatta</i>)	38.8(37.2-40.2)
16	Bat (<i>Pipistrellus noctula</i>)	31.5(30.0-33.0)	99	Monkey (<i>M. syanomalga</i>)	37.8(36.7-38.5)
17	Bat (<i>Plecotus auritus</i>)	36.6(35.0-38.2)	100	Monkey (<i>Papio hamadryas</i>)	38.1(37.3-38.7)
18	Bat, big brown (<i>Eptesicus tenuipinnis</i>)	35.7(32.2-39.2)	101	Monkey, night (<i>Aotes trivirgatus</i>)	38.2(37.4-40.0)
19	Bat, big brown (<i>E. serotinus</i>)	38.1(36.2-40.0)	102	Monkey, velvet (<i>Cercopithecus patus</i>)	38.0(37.4-38.5)
20	Bat, horseshoe (<i>Hipposideros caffra</i>)	34.9(31.4-38.4)	103	Monkey, velvet (<i>C. pygerythrus</i>)	38.7(36.9-40.5)
21	Bat, horseshoe (<i>H. cyclops</i>)	34.8(31.4-38.2)	104	Moose (<i>Alces americana</i>)	39.4
22	Bat, horseshoe (<i>Rhinolophus ferrum-equinum</i>)	35.8(29.1-42.5)	105	Mouse, deer (<i>Peromyscus leucopus</i>)	37.4(33.6-41.2)
23	Bat, horseshoe (<i>R. hipposideros</i>)	35.9(34.4-37.4)	106	Mouse, deer (<i>P. maniculatus</i>)	37.9(35.7-40.1)
24	Bat, horseshoe (<i>R. landeri</i>)	32.8(28.0-37.6)	107	Mouse, house (<i>Mus musculus</i>)	36.5(35.2-37.9)
25	Bat, little brown (<i>Myotis myotis</i>)	37.6(35.6-39.6)	108	Mouse, jumping (<i>Zapus hudsonicus</i>)	37.3(35.3-39.3)
26	Bat, little brown (<i>M. mystacinus</i>)	37.2(36.2-38.2)	109	Mouse, meadow (<i>Microtus pennsylvanicus</i>)	39.3(34.7-43.1)
27	Bat, short-tailed (<i>Carollia perspicillata</i>)	37.4(36.4-37.8)	110	Mouse, pocket (<i>Perognathus hispidus</i>)	36.5(34.9-38.1)
28	Bear, black (<i>Ursus americanus</i>)	38.3(31.3-39.0)	111	Mouse, red-backed (<i>Clethrionomus gapperi</i>)	37.3(35.3-39.3)
29	Bear, brown (<i>U. arctos</i>)	38.0(37.0-38.0)	112	Mouse, red-backed (<i>C. rutilus</i>)	38.3(36.6-40.0)
30	Bear, polar (<i>U. -Thalarchos-maritimus</i>)	37.5(37.1-37.8)	113	Muntjac (<i>Muntiacus muntjac</i>)	38.6
31	Bison (<i>Bison bison</i>)	39.0	114	Musk ox (<i>Ovibos moschatus</i>)	40.0
32	Buffalo, water (<i>Bubalus spp.</i>)	38.2(37.4-38.7)	115	Muskkrat (<i>Ondatra zibethica</i>)	38.0(37.0-39.1)
33	Camel (<i>Camelus bactrianus</i>)	37.5(36.9-38.0)	116	Nutria (<i>Myocastor coypus</i>)	38.0(37.2-38.8)
34	Caribou (<i>Rangifer tarandus stonei</i>)	39.0(38.5-40.0)	117	Opossum (<i>Didelphis marsupialis</i>)	34.6(31.9-36.4)
35	Cat (<i>Felis catus</i>)	33.6(32.2-39.9)	118	Opossum (<i>D. virginiana</i>)	34.2(32.6-36.6)
36	Cat, ring-tail (<i>Bassariscus astutus</i>)	37.6(37.2-37.9)	119	Opossum, brown (<i>Metachirus nudicaudatus</i>)	34.4(32.4-36.4)
37	Cat, tiger (<i>Dasyurus maculatus</i>)	35.6(32.2-37.2)	120	Opossum, brush-tail (<i>Trichosurus vulpecula</i>)	36.1(35.4-36.8)
38	Chimpanzee (<i>Pan troglodytes</i>)	37.2(36.3-37.8)	121	Opossum, Murine (<i>Marmosa mexicana</i>)	32.7(28.9-36.5)
39	Chipmunk (<i>Tamias striatus</i>)	38.6(36.5-40.1)	122	Opossum, ring-tail (<i>Pseudocheirus vulpina</i>)	35.1(33.1-36.6)
40	Chipmunk, least (<i>Eutamias minimus</i>)	38.7(35.8-41.6)	123	Orangutan (<i>Pongo pygmaeus</i>)	37.0(36.2-37.8)
41	Coati (<i>Nasua rufa</i>)	38.2(37.1-39.2)	124	Otter, sea (<i>Enhydra lutris</i>)	38.5
42	Cow, beef (<i>Bos taurus</i>)	38.3(36.7-39.1)	125	Panther (<i>Felis concolor</i>)	38.1(37.2-39.1)
43	Cow, dairy (<i>B. taurus</i>)	38.6(38.0-39.3)	126	Peccary (<i>Tayassu angulatus</i>)	38.7
44	Cow, Holstein	39.6(38.2-41.0)	127	Pig (<i>Sus scrofa</i>)	39.3(38.7-40.3)
45	Cow, Jersey	39.3(37.9-40.7)	128	Pika, collared (<i>Ochotona collaris</i>)	39.0
46	Deer (<i>Odocoileus virginianus</i>)	38.2(37.9-38.5)	129	Platypus (<i>Ornithorhynchus paradoxus</i>)	30.5(24.8-35.3)
47	Dog (<i>Canis familiaris</i>)	38.9(36.7-40.6)	130	Porcupine (<i>Coendou villosus</i>)	36.8(35.3-38.3)
48	Dog, Eskimo (<i>C. familiaris</i>)	38.5(37.2-40.0)	131	Porcupine (<i>Erethizon dorsatum</i>)	37.4(36.5-38.3)
49	Dormouse (<i>Glis glis</i>)	35.5(35.1-35.9)	132	Rabbit (<i>Oryctolagus cuniculus</i>)	38.8(37.5-40.1)
50	Dormouse (<i>Muscardinus avellanaris</i>)	34.5(31.0-37.9)	133	Rabbit, cottontail (<i>Sylvilagus floridanus</i>)	39.4(38.7-40.1)
51	Echidna (<i>Tachyglossus sp.</i>)	29.9(24.9-34.5)	134	Raccoon (<i>Necyctoreutes procyonoides</i>)	37.4(37.0-37.8)
52	Echidna (<i>T. aculeatus</i>)	29.4(27.4-31.4)	135	Raccoon (<i>Procyon lotor</i>)	38.3(37.3-39.7)
53	Echidna (<i>T. hystrix</i>)	28.7(25.7-31.7)	136	Rat (<i>Rattus rattus</i>)	35.1(32.1-38.1)
54	Echidna (<i>Zaglossus sp.</i>)	29.0(26.2-31.8)	137	Rat, spiny (<i>Proechimys semispinosus</i>)	37.9(36.5-39.3)
55	Eland (<i>Taurotragus oryx</i>)	38.8	138	Rat, white (<i>Rattus norvegicus</i>)	37.3(34.5-40.0)
56	Elephant (<i>Elephas maximus</i>)	36.2(35.7-37.8)	139	Reedbed (<i>Redunca arundinum</i>)	38.4
57	Ferret (<i>Mustela putorius</i>)	39.3(37.9-40.4)	140	Reindeer (<i>Rangifer tarandus</i>)	38.8(37.5-39.8)
58	Fox (<i>Vulpes melanotus</i>)	37.9(36.5-39.3)	141	Rhinoceros (<i>Rhinoceros unicornis</i>)	37.6(37.4-37.8)
59	Fox, Alaska red (<i>V. vulpes alascensis</i>)	40.1	142	Seal (<i>Callorhinus ursinus</i>)	38.3(37.4-39.5)
60	Fox, Arctic (<i>Alopex sp.</i>)	38.6(35.4-41.8)	143	Seal, bearded (<i>Erignathus barbatus</i>)	37.2(36.8-37.3)
61	Fox, Arctic (<i>Vulpes lagopus</i>)	38.7(38.1-39.3)	144	Sealion, Steller's (<i>Eumetopias jubata</i>)	38.5
62	Fox, Arctic white (<i>Alopex lagopus</i>)	38.6(36.6-41.5)	145	Sheep (<i>Ovis aries</i>)	38.8(37.2-40.5)
63	Fox, flying (<i>Pteropus gaddei</i>)	35.4(32.2-38.6)	146	Shrew, short-tail (<i>Blarina brevicauda</i>)	35.7(34.5-37.7)
64	Fox, flying (<i>Rousettus angolensis</i>)	36.5(34.4-38.6)	147	Skunk (<i>Mephitis mesomelas</i>)	36.4(36.3-36.5)
65	Fox, red (<i>Vulpes fulva</i>)	38.8(37.5-40.1)	148	Sloth, three-toed (<i>Bradypus cuculliger</i>)	31.0(24.4-37.6)
66	Fox, red (<i>V. vulpes</i>)	37.8(37.6-38.0)	149	Sloth, three-toed (<i>B. griseus</i>)	33.2(29.9-37.7)
67	Goat (<i>Capra hircus</i>)	39.5(38.3-40.8)	150	Sloth, two-toed (<i>Choloepus hoffmanni</i>)	34.5(33.4-35.8)
68	Goat, domestic (<i>C. sp.</i>)	39.2(37.8-40.5)	151	Squirrel, Arctic ground (<i>Citellus undulatus</i>)	38.5(32.5-41.0)
69	Goat, Indian (<i>C. sp.</i>)	38.6(35.2-40.5)	152	Squirrel, flying (<i>Glaucomys volans</i>)	37.0(35.0-39.0)
70	Goat, mountain (<i>Oreamnos americanus</i>)	38.6(37.8-39.0)	153	Squirrel, Franklin (<i>Citellus franklini</i>)	36.6(33.9-39.3)
71	Gopher, pocket (<i>Geomys bursarius</i>)	34.8(33.8-35.8)	154	Squirrel, red (<i>Tamiasciurus hudsonicus</i>)	39.6(37.6-41.6)
72	Guinea pig (<i>Cavia sp.</i>)	39.1(38.4-39.8)	155	Squirrel, thirteen-lined (<i>Citellus tridecemlineatus</i>)	36.9(33.0-40.8)
73	Guinea pig (<i>C. porcellus</i>)	37.9(36.0-40.5)	156	Squirrel, Yukon ground (<i>Citellus parryi</i>)	38.1(35.5-40.7)
74	Hamster (<i>Citellus auratus</i>)	36.9(36.4-37.4)	157	Wallaby (<i>Petrogale xanthopus</i>)	36.0(35.4-36.6)
75	Hamster (<i>Mesocricetus auratus</i>)	36.0(35.0-37.0)	158	Walrus (<i>Odobenus divergens</i>)	36.1
76	Hare, Arctic (<i>Lepus timidus</i>)	38.3	159	Weasel, least (<i>Mustela rixosa</i>)	40.4(38.4-42.4)
77	Hare, showshoe (<i>L. americanus</i>)	38.5(38.0-39.0)	160	Whale, blue (<i>Balaenoptera musculus</i>)	35.7(35.6-35.8)
78	Hare, varying (<i>L. americanus</i>)	39.6(38.9-40.3)	161	Whale, fin (<i>B. physalus</i>)	36.3(34.4-38.2)
79	Hare, white (<i>L. timidus</i>)	38.7(38.1-39.3)	162	Whale, gray (<i>Rachianectes glaucus</i>)	36.5(35.0-38.0)
80	Hedgehog (<i>Erinaceus europaeus</i>)	35.1(32.0-36.5)	163	Whale, humpback (<i>Megaptera nodosa</i>)	36.3(35.2-37.8)
81	Hippopotamus (<i>Hippopotamus amphibius</i>)	25.0 ¹	164	Whale, sperm (<i>Physeter catodon</i>)	35.8(34.6-37.0)
82	Horse (<i>Equus caballus</i>)	37.7(37.2-38.1)	165	Wolf (<i>Canis lupus</i>)	40.5
83	Hutia (<i>Capromys pilorides</i>)	38.3(36.2-40.3)			

/1/ Skin temperature. /2/ Old report; may be for a seal.

311. BODY TEMPERATURES (Concluded)

Part II: BIRDS

Temperatures are cloacal averages taken usually at room temperatures.

Species	Temperature, °C	Species	Temperature, °C
1 Albatross, wandering (<i>Diomedea exulans</i>)	40.7(39.5-41.9)	81 Hawk, marsh (<i>Circus hudsonius</i>)	41.9(41.4-42.4)
2 Albatross, yellow-nosed (<i>Thalassogeron chlororhynchus</i>)	41.0(40.7-41.3)	82 Hawk, red-tailed (<i>Buteo borealis</i>)	41.2(40.9-41.4)
3 Amazon, blue-fronted (<i>Amazona aestiva</i>)	41.0 ¹	83 Heron, black-crowned night (<i>Nycticorax nycticorax hoactli</i>)	42.3(41.9-42.4)
4 Auk, razor-billed (<i>Alca torda</i>)	39.1 ¹ (39.9-41.1)	84 Ibis, white (<i>Guara alba</i>)	42.3(42.2-42.4)
5 Bittern, American (<i>Botaurus lentiginosus</i>)	40.2 ¹	85 Jackdaw (<i>Coloeus monedula</i>)	41.2(41.0-42.6)
6 Bittern, sun (<i>Eurypyga helias</i>)	39.1 ¹	86 Jaeger, parasitic (<i>Stercorarius parasiticus</i>)	41.2
7 Blackbird, rusty (<i>Euphagus carolinus</i>)	42.3 ¹	87 Jay, blue (<i>Cyanocitta cristata</i>)	43.6(42.0-44.4)
8 Bluebird, eastern (<i>Sialia sialis</i>)	42.6(42.2-43.0)	88 Jay, brown (<i>Psittorhinus morio</i>)	43.3 ¹
9 Bobolink (<i>Dolichonyx oryzivorus</i>)	42.6(40.9-43.4)	89 Junco, slate-colored (<i>Junco hyemalis</i>)	43.0(41.2-44.0)
10 Brant (<i>Branta bernicla</i>)	42.7 ¹	90 Kittiwake (<i>Rissa tridactyla</i>)	41.4(39.9-42.2)
11 Bullfinch (<i>Pyrrhula pyrrhula</i>)	42.2	91 Kiwi, large gray (<i>Apteryx haasti</i>)	38.1 ¹
12 Bunting, snow (<i>Plectrophenax nivalis</i>)	43.1(42.9-43.4)	92 Kiwi, north island (<i>A. mantelli</i>)	37.8(37.4-38.2)
13 Bunting, yellow (<i>Emberiza citrinella</i>)	43.2	93 Knysna Lourie (<i>Tauracus corythaix</i>)	40.1 ¹
14 Cardinal, red-crested (<i>Paroaria cucullata</i>)	44.2 ¹	94 Lark, northern horned (<i>Otocoris alpestris</i>)	43.9 ¹
15 Cassowary, Beccari's (<i>Casuarus beccarii</i>)	39.2	95 Motmot, Brazilian (<i>Momotus paraensis</i>)	40.0 ¹
16 Cassowary, two-wattled (<i>C. bicarunculatus</i> intensus)	38.8	96 Murre (<i>Uria troile</i>)	40.3(39.4-41.0)
17 Catbird (<i>Dumetella carolinensis</i>)	41.2(40.0-42.3)	97 Murre, Atlantic (<i>U. aalge</i>)	40.9(40.4-41.4)
18 Chickadee, black-capped (<i>Parus atricapillus</i>)	43.8(43.2-44.3)	98 Murre, thick-billed (<i>U. lomvia</i>)	40.5(39.7-41.5)
19 Chough, Alpine (<i>Pyrrhocorax alpinus</i>)	42.0	99 Ostrich (<i>Struthio camelus</i>)	39.2(37.8-40.0)
20 Coot, European (<i>Fulica atra</i>)	40.5 ¹	100 Owl, great-horned (<i>Bubo virginianus</i>)	40.5(40.3-40.8)
21 Cormorant, common (<i>Phalacrocorax carbo</i>)	39.6(38.9-40.3)	101 Owl, northern barred (<i>Strix varia</i>)	40.0(39.6-40.5)
22 Cormorant, double-crested (<i>P. auritus</i>)	41.3(41.0-41.5)	102 Owl, snowy (<i>Nyctea nyctea</i>)	41.0(40.9-41.7)
23 Cowbird (<i>Molothrus ater</i>)	43.2(42.5-43.5)	103 Peacock (<i>Pavo cristatus</i>)	40.0(39.5-40.3)
24 Crane, demoiselle (<i>Anthropoides virgo</i>)	41.1 ¹	104 Pelican, white (<i>Pelecanus erythrorhynchos</i>)	40.5 ¹
25 Crane, sandhill (<i>Grus canadensis</i>)	41.3(41.0-41.4)	105 Penguin, little (<i>Eudyptula minor</i>)	39.0(37.8-40.1)
26 Crossbill, red (<i>Loxia curvirostra pusilla</i>)	43.3(43.1-43.6)	106 Petrel, pintado (<i>Daption capensis</i>)	39.8(39.3-40.2)
27 Crossbill, white-winged (<i>L. leucoptera</i>)	43.0(42.5-44.0)	107 Petrel, snow (<i>Pagophila eburnea</i>)	40.4(39.9-41.2)
28 Crow, eastern (<i>Corvus brachyrhynchos</i>)	43.0 ¹	108 Petrel, storm (<i>Hydrobatas pelagica</i>)	39.7 ¹
29 Curassow, black (<i>Crax bignoni</i>)	42.0	109 Pewee, eastern wood (<i>Myiochanes virens</i>)	41.6(39.6-43.0)
30 Curassow, Central American (<i>C. rubra</i>)	41.3	110 Pheasant, Amherst (<i>Chrysolophus amherstiae</i>)	42.2(41.9-42.4)
31 Dove, eastern turtle (<i>Streptopelia decaocto</i>)	43.3(43.0-43.9)	111 Pheasant, golden (<i>C. pictus</i>)	42.5(42.2-42.5)
32 Dove, mourning (<i>Zenaidura macroura</i>)	43.4(42.9-43.6)	112 Pheasant, ring-necked (<i>Phasianus colchicus mongolicus</i>)	42.1(41.7-42.4)
33 Dove, quail (<i>Oreopelia montana</i>)	43.3 ¹	113 Pheasant, ring-necked (<i>P. torquatus</i>)	41.5
34 Duck, black (<i>Anas rubripes</i>)	41.0(40.7-41.5)	114 Pheasant, silver (<i>Gennaeus nycthemerus</i>)	42.3(42.2-42.4)
35 Duck, domestic (<i>A. platyrhynchos domesticus</i>)	41.5(40.9-42.0)	115 Pigeon, Cape Rock (<i>Columba phaeonota</i>)	43.3 ¹
36 Duck, mallard (<i>A. platyrhynchos</i>)	43.1(42.8-43.4)	116 Pigeon, domestic (<i>C. livia</i>)	41.1(39.9-41.9)
37 Duck, muscovy (<i>Cairina moschata</i>)	42.0(40.8-42.3)	117 Pintail (<i>Dafila acuta tzitzihua</i>)	43.0(42.8-43.2)
38 Duck, shield (<i>Tadorna tadorna</i>)	42.7(42.4-42.9)	118 Puffin, Atlantic (<i>Fratercula arctica</i>)	40.8(40.7-40.8)
39 Duck, wood (<i>Aix sponsa</i>)	42.0	119 Quail, Calif. (<i>Lophortyx californica vallicola</i>)	42.9 ¹
40 Eider, American (<i>Somateria mollissima dresseri</i>)	42.5(40.1-43.2)	120 Rail, clapper (<i>Rallus crepitans</i>)	40.1
41 Emu (<i>Dromiceius novaehollandiae</i>)	39.0	121 Redwing (<i>Agelaius phoeniceus</i>)	42.7(42.1-43.0)
42 Falcon, prairie (<i>Falco mexicanus</i>)	41.4 ¹	122 Road runner (<i>Geococcyx californianus</i>)	41.9
43 Field fare (<i>Turdus pilaris</i>)	43.6	123 Robin, eastern (<i>Turdus migratorius</i>)	43.6(43.2-44.2)
44 Finch, eastern purple (<i>Carpodacus purpureus</i>)	43.2(42.5-43.8)	124 Scap, greater (<i>Marila marila</i>)	42.6(42.2-43.2)
45 Finch, green (<i>Ligurinus chloris</i>)	41.5(41.2-42.2)	125 Scoter, black (<i>Oidemia nigra</i>)	41.3(40.9-41.7)
46 Flamingo (<i>Phoenicopterus chilensis</i>)	40.5(40.4-40.6)	126 Screech-owl, eastern (<i>Otus asio naevius</i>)	40.1 ¹
47 Fowl, domestic (<i>Gallus gallus</i>)	41.4(40.9-41.9)	127 Shag (<i>Phalacrocorax graculus</i>)	40.4(39.4-40.9)
48 Francolin, gray-winged (<i>Francolinus natalensis</i>)	42.2	128 Shearwater, slender-billed (<i>Puffinus tenuirostris</i>)	38.6(37.8-39.6)
49 Fulmar (<i>Fulmarus glacialis</i>)	38.8(38.1-39.6)	129 Shearwater, slender-billed (<i>Puffinus tenuirostris</i>)	40.0
50 Gadwall (<i>Anas strepera</i>)	42.9 ¹	130 Skua (<i>Megalestris skua</i>)	40.1(39.5-40.8)
51 Gannet (<i>Morris bassana</i>)	40.9(40.2-41.5)	131 Snow-goose, greater (<i>Chen hyperborea atlantica</i>)	40.8(40.6-41.2)
52 Goldeneye (<i>Clangula clangula</i>)	40.4 ¹	132 Sparrow, Cassin's (<i>Aimophila cassinii</i>)	42.2 ¹
53 Goose, barnacle (<i>Branta leucopsis</i>)	40.2(39.9-41.5)	133 Sparrow, eastern chipping (<i>Spizella passerina</i>)	41.7(39.8-42.9)
54 Goose, bean (<i>Anser fabalis</i>)	40.9	134 Sparrow, eastern fox (<i>Passerella iliaca</i>)	43.8(42.7-44.3)
55 Goose, blue (<i>Chen caerulescens</i>)	40.4(40.2-40.8)	135 Sparrow, eastern song (<i>Melospiza melodia</i>)	41.1(40.2-43.0)
56 Goose, cackling (<i>Branta canadensis minima</i>)	41.1(40.7-41.5)	136 Sparrow, eastern tree (<i>Spizella arborea</i>)	43.0(42.3-44.0)
57 Goose, Canada (<i>B. canadensis</i>)	40.5(39.8-41.3)	137 Sparrow, house (<i>Passer domesticus</i>)	41.5(37.3-43.5)
58 Goose, Chinese (<i>Cygnopsis cygnoides</i>)	42.8(42.4-43.3)	138 Sparrow, Lincoln's (<i>Melospiza lincolni</i>)	43.6
59 Goose, domestic (<i>Anser anser domesticus</i>)	41.3(40.2-42.0)	139 Sparrow, sharp-tailed (<i>Passerherbulus caudatus</i>)	42.9
60 Goose, Hutchins (<i>Branta canadensis hutchinsii</i>)	40.5(40.0-41.0)	140 Sparrow, white-crowned (<i>Zonotrichia leucophrys</i>)	43.4(41.4-44.7)
61 Goose, white-fronted (<i>Anser albifrons</i>)	40.5(40.6-42.7)	141 Sparrow, white-throated (<i>Z. albicollis</i>)	43.2(41.5-44.2)
62 Goshawk, crested (<i>Accipiter trivirgatus</i>)	41.8(40.2-42.2)	142 Sparrow hawk (<i>Falco sparverius</i>)	42.3(42.0-43.2)
63 Grackle, bronzed (<i>Quiscalus quiscula aeneus</i>)	43.5(42.5-44.0)	143 Starling (<i>Sturnus vulgaris</i>)	43.5(38.8-43.7)
64 Grosbeak, Canadian pine (<i>Pinicola enucleator leucura</i>)	42.6(42.0-43.2)	144 Swan, black (<i>Chenopsis atratra</i>)	40.6(40.0-41.0)
65 Grosbeak, eastern evening (<i>Hesperiphona vespertina</i>)	43.3(42.8-43.9)	145 Swan, mute (<i>Cygnus olor</i>)	41.0(40.9-41.2)
66 Grosbeak, rose-breasted (<i>Hedymeles ludivicianus</i>)	43.6(43.2-43.9)	146 Swift, European (<i>Micropus apus</i>)	44.0
67 Grouse, ruffed (<i>Bonasa umbellus togata</i>)	42.5 ¹	147 Thrasher, brown (<i>Toxostoma rufum</i>)	43.1 ¹
68 Guillemot, black (<i>Cephus grylle</i>)	40.7(40.0-41.0)	148 Thrush, red-winged (<i>Turdus musicus</i>)	41.0(38.4-42.7)
69 Guinea fowl (<i>Numida meleagris</i>)	42.2(42.0-43.3)	149 Thrush, wood (<i>Hylocichla mustelina</i>)	40.9(39.2-42.1)
70 Gull, American herring (<i>Larus argentatus smithsonianus</i>)	41.4(40.8-41.9)	150 Tinamou, rufescent (<i>Rhynchotus rufescens</i>)	40.8
71 Gull, black-headed (<i>L. ridibundus</i>)	41.4 ¹	151 Tinamou, spotted (<i>Nothura maculosa</i>)	40.5(39.2-42.4)
72 Gull, common (<i>L. canus</i>)	41.8(41.0-42.0)	152 Titmouse, great (<i>Parus major</i>)	44.0
73 Gull, glaucous (<i>L. hyperboreus</i>)	40.8(39.8-41.7)	153 Tree-duck, black-bellied (<i>Dendrocygna autumnalis</i>)	42.3 ¹
74 Gull, great black-backed (<i>L. marinus</i>)	41.9(41.2-42.4)	154 Turkey (<i>Meleagris gallopavo</i>)	42.8
75 Gull, herring (<i>L. argentatus</i>)	42.3(41.6-43.0)	155 Vulture, bearded (<i>Gypaetus barbatus</i>)	41.0
76 Gull, laughing (<i>L. atricilla</i>)	42.3(41.7-42.8)	156 Warbler, Connecticut (<i>Oporornis agilis</i>)	42.5 ¹
77 Gull, lesser black-backed (<i>L. fuscus</i>)	41.7(41.2-42.1)	157 Waxwing, Bohemian (<i>Bombicilla garrula</i>)	42.5(41.2-42.1)
78 Hawk, Amer. rough-legged (<i>Buteo lagopus johannis</i>)	42.0(41.9-42.0)	158 Waxwing, cedar (<i>B. cedrorum</i>)	42.9(42.0-44.4)
79 Hawk, broad-winged (<i>B. platyterus</i>)	41.0 ¹	159 Wigeon, European (<i>Mareca penelope</i>)	42.5(41.4-43.0)
80 Hawk, rough-legged (<i>Archibuteo lagopus</i>)	41.0 ¹	160 Wren, eastern house (<i>Troglodytes aedon</i>)	41.1(39.2-42.1)

/1/ Only one measurement recorded.

312. HIBERNATION: VERTEBRATES

Hibernation in mammals is defined as a state characterized by a lowering of body temperature to near that of the environment with a concurrent decrease in metabolism, but with the ability to regain the elevated body temperature without heat from external sources. Among reptiles and amphibians hibernation is arbitrarily defined as the state where body temperature approaches or equals ambient temperature, and metabolic, respiratory and heart rates are greatly reduced.

Species		Geographical Distribution	Temperature		Heart Rate per min	Respiration Rate per min	O ₂ Consumption ml/g/hr ¹	CO ₂ Pro- duced ml/g/hr	RQ ²
			Air °C	Rectal °C					
Mammalia									
1	Insectivora								
2	Hedgehog (<i>Erinaceus europaeus</i>)	Great Britain to Spain, Italy, Greece	2-3	6.2-7.7	18-24		0.014-0.033		
3			3.5	5			0.88	0.83	0.68
4			6				0.40	0.29 ³	0.73
			9.7	12.0			0.126	0.056	
5	Chiroptera								
6	Bat, big brown (<i>Eptesicus fuscus</i>)	U.S.A., southern Canada	8	9		3-10 ⁴			
7			22-26				0.8		
8	Bat, little brown (<i>Myotis lucifugus</i>)	Northern U.S.A., southern Canada, and southern Alaska	23	23.2		72-80	0.45		
9			0.5				0.113		
10	Bat, greater horseshoe (<i>Rhinolophus ferrum-equinum</i>)	England to Korea, Japan to Morocco	13	13	7-10		0.022-0.039	0.089	
11			19	19			0.426	0.366	0.77
12	Bat, lesser horseshoe (<i>R. hipposideros</i>)	Europe to Asia Minor, north-western India to Sudan	15	15			2.23	1.80	0.80
13	Bat, Keen (<i>Myotis keenii</i>)	Eastern U.S.A., British Columbia	21.5	22.7		140-168	0.85		
14	Bat, long-eared (<i>Plecotus auritus</i>)	Europe to Japan, eastern Siberia to Sudan	0				0.037		
15			5	6.5			0.069	0.049 ³	0.71
16			10	10.7			0.094	0.079 ³	0.84
17	Bat, large mouse-eared (<i>Myotis myotis</i>)	Europe to China to Afghanistan	1.7				0.020	0.009	
18			2.5				0.051	0.033	0.65
19	Bat, noctule (<i>Nyctalus noctula</i>)	Europe to Siberia, Japan to Palestine	4.3				0.51	0.38 ³	0.75
20			12.5				3.49 ⁵	2.58 ³	0.74
21			20				0.403 ³	0.314	0.78
22			30				0.682 ³	0.484	0.71
23	Bat, parti-colored (<i>Vespertilio murinus</i>)	Europe to Japan, north-western India	0				0.037		
24			7.05	7.05	50-55				
25			8				0.020		
26	Pipistrelle (<i>Pipistrellus pipistrellus</i>)	Europe to North Asia, Japan	5	5			0.247	0.175 ³	0.71
27							0.053	0.038 ³	0.72
Rodentia									
28	Dormouse, common (<i>Muscardinus avellanarius</i>)	Southern Italy to England and Sweden	6			9-10			
29			10.1				0.80	0.57 ³	0.71
30			11.6		10-12				
31	Dormouse, fat (<i>Myoxus glis</i>)	Central and southern Europe	6				0.029	0.021 ³	0.72
32			11.8				0.024		
33	Hamster, golden (<i>Mesocricetus auratus</i>)	Rumania, eastern Asia Minor, Syria, Palestine, north-western Iran	5	5-6			0.183	0.132 ³	0.72
34			5.5	5.5 ⁶			0.032		
35			5.8	6.4 ⁶			0.06		
36			5	5	4-15		0.060-0.080		
37	Marmot, European (<i>Marmota marmota</i>)	Alps	10	10.5		0.35 ⁴	0.018	0.012	0.68
38	Squirrel, arctic ground (<i>Citellus undulatus</i>)	Northeastern Siberia, Alaska, northern Canada	5.9	5.2	68 ⁷	10			
39			5.9	5.9		6			
40	Squirrel, thirteen-lined ground (<i>C. tridecemlineatus</i>)	Central U.S.A., Canada		3-10 ⁶	5-20		0.081-0.191		
41			4.0	5.7		1	0.081		
42			8.6	10.2		1.6	0.125		
43			12.5	13.6		1.8	0.197		
44	Suslik (<i>Citellus citellus</i>)	Central Asia, southern Russia to Austria	6				0.320	0.230 ³	0.72
45			7	7.2			0.015		
46			11	11.7		5			
47			13	15.5			0.034		
48	Woodchuck (<i>Marmota monax</i>)	Eastern U.S.A., Canada, Alaska	4-7		4-5		0.008-0.034		
49			8	8		6			
Carnivora									
50	Bear, black (<i>Ursus americanus</i>) ⁸	North America, north of Mexico	-3.5	31.2					
51			4.4	35.5		2-3			
Aves									
52	Hummingbird, Allen's (<i>Selasphorus sasin</i>)	U.S.A. (California)	16	21.5					
53			22				1.24		
54	Hummingbird, Anna (<i>Calypete anna</i>)	U.S.A. (California)	24				0.84		
55	Swift, European (<i>Micropus apus</i>)		19	23 ⁹		8-10 ⁴	0.7	0.31	
56	Poorwill (<i>Phalaenoptilus nuttalli</i>)	Western U.S.A., Mexico	17.5	19.8					
Reptilia									
57	Lizard, horned (<i>Phrynosoma cornutum</i>)	U.S.A. (Kansas to Texas), northern Mexico to Colorado	4-6 ¹⁰				0.051	0.022	
58			0-20 ¹¹				0.043	0.033	0.73
Amphibia									
59	Frog (<i>Rana esculenta</i>)		0	1			0.043	0.059	
60			6.1	6.4			0.342	0.449	

/1/ Milliliters per gram of body weight per hour. /2/ Respiratory quotient. Probably does not reflect actual exchange of gases or the true nature of combustion of foods during hibernation. /3/ Calculated. /4/ Respiration rates are very irregular in deep hibernation and there may be several minutes with no respiration followed by several respirations. Cheyne-Stokes respiration is not uncommon; range is average of several minutes. /5/ During awakening from hibernation. /6/ Oral temperature. /7/ Feeble heart beat in deep hibernation, becoming more evident as awakening progresses. /8/ Not a true hibernator, as indicated by the discrepancy between rectal and ambient temperature. /9/ Proventriculus temperature, taken orally. /10/ Body temperature in reptiles and amphibians presumably at or near ambient temperature. /11/ Range is result of long duration of experiments.

313. DIAPAUSE: INSECTS AND MITES

Diapause may be defined generally as a stoppage or radical decline of growth or physiological processes, usually for purposes of enduring extremes of such environmental factors as temperature and humidity. The degree to which purely physiological factors induce diapause cannot be stated with accuracy, if at all. There is no complete agreement on the nature or scope of the phenomenon, nor even whether it be a single phenomenon described inter- or intra-specifically.

Species	Dormant Stage ¹	Type of Diapause ²	Observed Characteristics ³	Species	Dormant State	Type of Diapause ²	Observed Characteristics ³
Acarina				Lepidoptera (concluded)			
1 Metatetranychus ulmi	E-1	F	abcd	28 Bombyx mori	E-1	F	acdhi
2 Tetranychus telarius	A	F	acd	29 univoltine races	E-1	O	acdhi
Coleoptera				30 Chorizabrotis auxiliaris	A	O	dk
3 Anatolica eremita	A	?	di	31 Cydia pomonella	L-2	F	acd
4 Dytiscus marginalia	A	O	g	32 Dendrolimus pini	L-1 to L-2	F	c
5 Epilachna corrupta	A	F		33 Diataraxia oleracea	P	F	acd
6 Leptinotarsa decemlineata	A	F	cdgi	34 Euproctis chrysorrhoea	L-1	F	c
Diptera				35 Grapholitha molesta	L-2	F	acd
7 Epistrophe balteata	A	F		36 Harrisina brillians	P	F	c
8 E. bifasciata	L-2	O	di	37 Loxostege sticticalis	L-2	F	
9 Lucilia sericata	L-2	F	d	38 Lymantria dispar	E-2	O	d
10 Sitodiplosis mosellana	L-2	O		39 Malacosoma disstria	E-2	O	
Hemiptera				40 Mamestra brassicae	P	F	acd
11 Eurydema ornatum	A	F	ad	41 Operophtera brumata	P	O	d
12 Eurygaster integriceps	A	O		42 Philosamia cynthia	P	F	dei
13 Psylla pyri	A	F	acd	43 Pieris brassicae	P	F	acd
14 Reduvius personatus	L-1 to L-2	F	ad	44 Platysamia cecropia	P	O	deij
Hymenoptera				45 Polychrosis botrana	P	F	c
15 Apanteles glomeratus	PP	F	c	Pyrausta nubilalis			
16 Cephus cinctus	PP	O	de	46 bivoltine race	L-2	F	ad
17 Exeristes roborator	L-2	F	d	47 univoltine race	L-2	O	ad
18 Gilpinia polytoma	PP	O	d	48 Telea polyphemus	P	?	adei
19 Sceliphron caementarium	L-2	?	i	Odonata			
20 Spalangia drosophilae	L-2	F	a	49 Anax imperator	L-2	F	c
21 Trichogramma cacaeciae	L-2	?		Orthoptera			
Neuroptera				50 Austroicetes cruciata	E-1	O	d
22 Sialis lutaria	L-2	?	f	51 Doclostaurus maroccanus	E-1	O	d
Lepidoptera				52 Gryllus commodus	E-1	O	d
23 Acronicta rumicis	P	F	ac	53 Gryllus campestris	L-2	?	e
24 Alsophila pometaria	E	O	d	54 Locusta migratoria gallica	E-1	O	d
25 Antheraea pernyi	P	F	cde	55 Locustana pardalina	E-1	?	d
26 Aporia crataegi	L-1	O	d	56 Melanoplus bivittatus	E-2	O	d
27 Araschnia levana	P	F	c	57 M. differentialis ⁴	E-1	O	di

/1/ A = adult; E = egg; E-1 = embryo small or half-grown; E-2 = embryo fully grown and nearly ready to hatch; L-1 = larva at close of early or intermediate instar; L-2 = larva at close of final or penultimate instar; P = pupa; PP = prepupa. /2/ F = facultative; O = obligate. /3/ a = dormant condition evoked by certain temperatures; h = dormant condition evoked by nutritional factors; c = dormant condition evoked by day lengths; d = diapause terminated by adequate exposure to a specific (often rather low) temperature range; e = failure of brain responsible for growth arrest in larvae and pupae; f = failure of prothoracic gland hormones responsible for growth arrest in larvae and pupae; g = corpus allatum involved in reproductive diapause of adult; h = egg diapause elicited when maternal blood contains secretion from subesophageal ganglion; i = diapause usually accompanied by striking fall in metabolic rate; j = metabolic rate decrease mediated by enzymatic processes, particularly in disappearance of cytochrome-c from tissues; k = diapause termination affected by rising humidity. /4/ Example of species in which diapause does not necessarily occur in all individuals. By selection over several generations, 100% non-diapausing or 100% long-diapausing embryos may be obtained.

314. PHYSIOLOGICAL CHANGES IN SLEEP: MAN

Data are intended to reflect changes caused by sleep alone as opposed to changes caused by rest, relaxation, or recumbency. Entries designated by "no change" are not to be construed to contraindicate profound changes sometimes found from the daytime active state to the relaxed horizontal state.

↑ = Increase; ↓ = Decrease.

Function or Property	Change in Sleep or Night/Day Ratio(N/D)	Function or Property	Change in Sleep or Night/Day Ratio (N/D)
1 Calcium, total, serum	No change; ↓ with rest	31 Effective renal plasma flow	No change
2 Chloride, serum	No change	32 H ₂ O, tubular reabsorption	N/D: 1.4
3 CO ₂ , combining power	No change or ↓	33 17-Ketosteroid excretion	N/D: 0.7
4 Creatinine, plasma	No change	34 Nitrogen, amino acid excretion	↓
5 Eosinophil count	↑	35 Nitrogen, total excretion	No change, or ↓
6 Glucose	No change	36 Phosphate excretion	↑
7 Hematocrit	No change; ↓ with rest	37 Phosphate excretion, fasting state	↓
8 Hemoglobin	No change; ↓ with rest	38 Potassium excretion	N/D: 0.25-0.5
9 pH	No change	39 Purine body excretion	↑
10 O ₂ , arterio-venous difference	No change	40 Sodium excretion	N/D: 0.14-0.72
11 Phosphorus, inorganic	↑	41 Specific gravity, urine	↑
12 Potassium, serum	No change	42 Titratable acidity	↑
13 Protein, plasma	No change; ↓ with rest	43 Urea excretion	No change
14 Sodium, serum	No change	44 Uric acid excretion	↓
15 Volume, plasma	No change; ↑ with rest	45 Urine flow	N/D: 0.5-0.83
16 Blood pressure, systolic	↓ 15-30 mm Hg	46 Uropepsin, urine	N/D: 0.7
17 Blood pressure, diastolic	↓ 5-10 mm Hg	47 Metabolic rate ²	No change or ↓ 10%
18 Cardiac output	↓	48 Babinski sign	Positive
19 Heart rate	↓	49 Knee jerk	↓ or abolished ³
20 Pulse pressure	↓ 10 mm Hg	50 Pupillary light reflex	↓
21 Vessels of extremities	Dilate	51 Time spent in movements	↓; 20-43 sec/hr
22 Gastric acidity, total	↑; 74 ml N/10 NaOH equiv.	52 Number of major movements	↓; 11-28/night
23 Gastric acidity, free HCl	↑; 59 ml N/10 NaOH equiv. ¹	53 Cerebral blood flow	N/D: 1.08 ⁴
24 Gastric motility	↑	54 Electroencephalogram	Delta waves appear ⁵
25 Saliva, pH	↑ to 6.3	55 Intracranial pressure	↓
26 Ammonium excretion, rate	↑	56 Temp., cortical and hypothalamic	↓
27 Bicarbonate excretion, rate	↓	57 Respiration rate	No change, ↑ or ↓
28 Calcium excretion, rate	No change or ↓	58 Respiratory rhythm, light sleep	Irregular
29 Chloride excretion, rate	N/D: 0.1-0.16	59 Respiratory rhythm, deep sleep	Regular
30 Creatinine excretion, rate	No change	60 Ventilation	↑ to 4.5 L/min

/1/ Almost none present, also reported. /2/ Slight decrease in body temperature also occurs. /3/ Similar response during relaxation.

/4/ Calculated. /5/ Also, alpha waves eventually disappear.

315. ENERGY COST, WORK: MAN

Wherever necessary in calculating these values, the following assumptions were made: surface area of the average man = 1.8 sq m (height, 173 cm; weight, 68 kg); surface area of the average woman = 1.65 sq m (height, 165 cm; weight, 60 kg).

Activity	Subjects no.	Tests no.	Age yr	Weight kg	Cal/min	Increase over Supine %
Men						
1 Supine, basal	82				1.17	
2 Supine, basal	5	15	19-25		1.19	
3 Lying, at ease	5	15	19-25		1.5	28
4 Sitting at ease	5	5	19-25		1.8	54
5 Sitting, calculating	5	7	19-25		1.78	52
6 Sitting, writing	4	4	19-25		1.91	63
7 Sitting, reading	2	2	19-25		1.98	69
8 Standing, at ease	5	8	19-25		1.98	69
9 Standing, relaxed	2	47			1.25	7
10 Dressing	9		18-20	69	4.0	242
11 Brushing clothes	1	3	28		2.57	120
12 Washing hands, face, neck; brushing hair	1	3	28		2.74	134
13 Cleaning shoes	2	2	19-25		3.49	198
14 Dressing, washing, shaving	5	8	19-25		3.56	204
15 Walking (indoors), 2.4 mi/hr	4	4	19-25		4.3	268
16 Walking (indoors), 3.0 mi/hr	4	6	19-25		5.1	336
17 Walking (outdoors), 4.0 mi/hr	1	1	19-25		8.2	601
18 Walking (outdoors), 4.2 mi/hr	4	5	19-25		9.1	678
19 Walking (outdoors), 4.4 mi/hr	4	8	19-25		9.5	712
20 Walking (outdoors), 4.6 mi/hr	3	4	19-25		9.9	746
21 Walking (outdoors), 4.8 mi/hr	5	6	19-25		10.7	815
22 Walking up and down stairs, 97/min	5	10	19-25		8.4	618
23 Walking up and down stairs, 116/min	5	5	19-25		9.3	695
24 Climbing 15 cm stairs, 14.8 m/min				75	9.8	736
25 Climbing 15 cm stairs, 17.6 m/min				75	10.3	780
26 Climbing ladder, 17 cm step, 50° angle, 9.1 m/min					7.7	558
27 With 50 lb					14.3	1122
28 Climbing ladder, 17 cm step, 90° angle, 11.9 m/min					11.5	883
29 With 50 lb					25.4	2071
30 Walking, hard snow, 6 km/hr	1			83	11.9	917
31 Walking, loose snow, 20 kg load, 4 km/hr	1			83	20.2	1627
32 Walking, snow shoes, soft snow, 4 km/hr	1			83	13.8	1080
33 Skiing, level hard snow, 6 km/hr	1			83	9.9	746
34 Driving car	3	19		64	2.8	139
35 Driving motor cycle	3	19		64	3.4	191
36 Bicycling, 5.5 mi/hr	1			71	4.5	285
37 Bicycling, 9.4 mi/hr	1			71	7.0	498
38 Bicycling, 13.1 mi/hr	1			71	11.1	849
39 Rowing, 33 strokes per minute	5	7			19.0	1524
40 Rowing, 22 strokes per minute	2	2			12.3	951
41 Peeling potatoes	1	1	19-25		2.7	131
42 Laboratory work	5	5	19-25		3.2	174
43 Washing dishes	3	3	19-25		3.3	182
44 Making beds	1	1	19-25		7.0	498
45 Cleaning windows	10	27		61	3.7	216
46 Copper tooling (sitting)	2	2	41		1.8	54
47 Hand loom weaving (sitting)	1	1	40		1.9	62
48 Chip carving (reclining)	1	2	40		2.0	71
49 Miscellaneous office work, sitting	10	36		55-72	1.6	37
50 Miscellaneous office work, standing	10	45		55-72	1.8	55
51 Shoemaking, shoe repair	6	17			2.7	131
52 Shoemaking, shoe manufacturing	4	16			3.0	156
53 Locksmith, working	1	5	19	53	2.5	114
54 Tailor, cutting	2	21		63	2.6	122
55 Tailor, pressing	2				3.9	233
56 Armature winding	2	8			2.2	88
57 Radio mechanics	4	8			2.7	131
58 Printing, hand compositor	1	1			2.2	88
59 Printing, printer	1	1			2.2	88
60 Watch and clock repairer trainee		8			1.6	37
61 Light assembly line		3			1.8	54
62 Draftsman		5			1.8	54
63 Light machine work (engineering)		8			2.4	105
64 Typewriter mechanic trainee		6			2.1	80
65 Medium assembly work		14			2.7	131
66 Sheet metal worker		8			3.0	156
67 Machinists (engineering)		12			3.1	165
68 Plastic moulding		9			3.3	182
69 Joiners		18			3.6	208
70 Turners		4			3.7	216
71 Tool room workers		4			3.9	233
72 Machine fitting		12			4.2	259
73 Casting lead balls in mould		2			4.8	310
74 Loading chemicals into mixer		2			6.0	413
75 Unloading battery boxes from oven		4			6.8	481
76 Shoveling, 8 kg load, 1 m lift, 12/min					7.5	541
77 Hewing with pick					7.0	498
78 Pushing wheelbarrow, 57 kg load, 4.5 km/hr					5.0	327
79 Bricklaying					4.0	242
80 Mixing cement					4.7	302
81 Stonemasonry, shaping stones					3.8	225
82 Plaster lathing					3.1	165
83 Plastering walls					4.1	250
84 Carpentry, measuring wood	1	35		62	2.4	105

315. ENERGY COST, WORK: MAN (Continued)

Wherever necessary in calculating these values, the following assumptions were made: surface area of the average man = 1.8 sq m (height, 173 cm; weight, 68 kg); surface area of the average woman = 1.65 sq m (height, 165 cm; weight, 60 kg).

Activity		Subjects no.	Tests no.	Age yr	Weight kg	Cal/min	Increase over Supine %
Men (concluded)							
85	Carpentry, machine sawing	1	35		62	2.4	105
86	Carpentry, joining floorboards	1	35		62	4.4	276
87	Carpentry, chiselling	1	31		65	5.7	387
88	Carpentry, sawing soft wood	1	31		65	6.3	439
89	Carpentry, drilling hard wood	1	35		62	7.0	498
90	Carpentry, sawing hard wood	1	31		65	7.5	541
91	Carpentry, planing soft wood	1	31		65	8.1	592
92	Carpentry, planing hard wood	1	31		65	9.1	678
93	Farming, mowing with horse drawn reaper	15		15-55		4.3	268
94	Farming, threshing, throwing sheaves to thresher	7		15-41		5.6	379
95	Farming, hoeing, deep ridging	5	13	24-36	57	9.5	712
96	Farming, hoeing		12			4.4	276
97	Farming, hand milking	1		28	64	4.7	302
98	Farming, machine milking	1		28	64	3.7	216
99	Farming, horse ploughing	7	16	18-39	57-86	5.9	404
100	Farming, tractor ploughing	7	22	18-39	57-86	4.2	259
101	Lumbering, tree felling	11				10.7	815
102	Lumbering, tree trimming	11				10.2	772
103	Lumbering, tree barking	11				10.1	763
104	Lumbering, crosscutting with bucksaw	11				9.0	669
105	Lumbering, stacking firewood	2				6.3	439
106	Lumbering, chopping, vertical, 1.25 kg ax, 19/min	1		23	82	6.9	490
107	Lumbering, chopping, horizontal, 1.25 kg ax, 34/min	1		23	82	13.2	1028
108	Coal mining, hewing	18				7.0	498
109	Coal mining, loading	20				7.1	507
110	Coal mining, timbering	18				5.7	387
111	Coal mining, drilling	30				5.8	396
112	Coal mining, pushing tubs	12				8.0	584
Women							
113	Supine, basal	49	265	22	55	.98	
114	Sitting	57	338	22	55	1.09	11
115	Standing	16	47	22	55	1.11	13
116	Dressing and undressing	12		8-12	34	2.3	135
117	Washing, dressing, undressing	3		43-55	70	3.3	237
118	Walking, 2.8 mi/hr	1	3	29		2.00	104
	Walking, 2.8 mi/hr, carrying a 20 lb load						
119	Load carried with shoulder yoke	1	3	29		1.94	98
120	Load carried on one shoulder	1	3	29		2.07	111
121	Load carried in two bundles in either hand	1	3	29		2.19	124
122	Load carried on tray in front of body	1	3	29		2.25	130
123	Load carried on tray in front of body with strap around shoulder	1	3	29		2.28	133
124	Load carried on head	1	3	29		2.49	154
125	Load carried on hip	1	3	29		2.72	178
126	Horizontal walking, 1.1 mi/hr	9	60	24		1.99	103
127	Horizontal walking, 2.2 mi/hr	9	64	24		2.84	190
128	Horizontal walking, 3.4 mi/hr	9	51	24		2.90	196
129	Skiing, level hard snow, moderate speed	1			57	10.8	1002
130	Skiing, uphill hard snow, maximum speed	1			68	18.6	1798
131	Washing dishes, top of pan 42 in. from floor (ht of subject 66 in.)	1	3			1.37	40
132	Washing dishes, top of pan 32 in. from floor (ht of subject 66 in.)	1	3			1.53	56
133	Paring potatoes (sitting)	7	24	27		1.23	26
134	Paring potatoes (standing)	7	26	27		1.29	32
135	Beating batter (standing)	7		22		1.43	46
136	Kneading dough (standing)	7		22		2.04	108
137	Step up 7 inches	9	36	26		2.77	183
138	Arm reach and trunk bend to 3 in. above floor (average ht of sub. 62 in.)	9	36	26		2.88	194
139	Arm reach and knee bend to 3 in. above floor (average ht of sub. 62 in.)	7	28	26		4.12	320
140	Arm reach and body pivot 36 in. above floor (average ht. of sub. 62 in.)	9	36	26		1.75	77
141	Arm reach 72 in. above floor (average ht of subjects 62 in.)	9	36	26		1.82	86
142	Hand sewing sheets, 18 stitches/min	1	5			1.18	20
143	Hand sewing sheets, 30 stitches/min	1	6			1.25	28
144	Darning	1	2	22		1.26	29
145	Crocheting, 32 stitches/min	1	5	22		1.27	30
146	Knitting, 23 stitches/min	1	4	22		1.29	31
147	Machine sewing (foot-operated)	1	8			1.43	46
148	Washing clothes, by hand	7	25	22		2.69	175
149	Rinsing clothes	7	21	22		2.42	147
150	Drying clothes (in extractor)	7	21	22		2.08	112
151	Wringing clothes, by hand	7	23	22		2.21	125
152	Putting up and removing clothes line	2	7	23		2.14	118
153	Hanging up clothes from basket on the floor	7	21	22		2.63	168
154	Ironing, standing (high board)	7	7	22		1.64	67
155	Ironing, standing (normal board)	7	7	22		1.69	72
156	Washing floor (on knees)	1	3	22		1.63	66
157	Sweeping floor	1	4	22		1.85	89
158	Vacuum-cleaning rug (moving 1 ft per sec)	1	10			1.63	66
159	Vacuum cleaning rug (moving 3 ft per sec)	1	12			2.58	163
160	Bedmaking, stripping	1		55	80	5.4	451
161	Typing, electric, 40 words per min	6			45-52	1.31	34
162	Typing, mechanical, 40 words per min	6			45-52	1.48	51
163	Typing, 59 words per min	1	4	18		1.34	37
164	Typing, 115 words per min	1	3	31		1.72	76
165	Leather tooling (reclining)	3	3	36		1.13	15
166	Leather tooling (sitting)	16	41	20		1.28	31
167	Leather stamping (sitting)	14	38	20		1.33	36

315. ENERGY COST, WORK: MAN (Concluded)

Wherever necessary in calculating these values, the following assumptions were made: surface area of the average man = 1.8 sq m (height, 173 cm; weight, 68 kg); surface area of the average woman = 1.65 sq m (height, 165 cm; weight, 60 kg).

Activity		Subjects no.	Tests no.	Age yr	Weight kg	Cal/min	Increase over Supine %
Women (concluded)							
168	Leather carving (sitting)	11	44	23		1.65	68
169	Leather lacing (sitting)	12	27	22		1.39	42
170	Copper tooling (sitting)	3	3	29		1.39	42
171	Chip carving (sitting)	17	53	22		1.61	64
172	Hand loom weaving	3	3	29		1.58	61
173	Table loom weaving	17	47	22		1.69	72
174	Floor loom weaving	3	4	42		2.12	116
175	Chisel carving, hardwood (sitting)	5	5	32		2.14	118
176	Chisel carving, softwood (sitting)	5	5	33		2.16	120
177	Printing (floor press, standing)	5	26	22		2.31	136
178	Hand sawing (standing)	16	47	22		3.27	234
179	Turning and finishing	8	36	19-33	47-65	3.0	206
180	Forging	4	20	22-32	55-69	3.1	216
181	Stamping	2	12	35-44	44-55	3.2	227
182	Hoisting shelf with pulley	1	5	54	56	3.3	237
183	Tool setting	5	25	21-26	45-59	3.4	247
184	Gauging	4	19	18-44	52-55	4.0	308
185	Laboring (general industrial)	5	14	35-51	44-86	5.1	420

316. ENERGY COST, PROGRESSION: MAN

Values for speed are kilometers per hour, unless otherwise indicated. Those for Calories are calculated on assumption that one liter of excess oxygen = 5.05 Calories, and that the resting level (included in the values) = 0.3 liters/min (1.46 Calories)¹.

Progression		Subject	Speed km/hr	Energy Cost		Progression		Subject	Speed km/hr	Energy Cost	
				Cal/min	LO ₂ /min					Cal/min	LO ₂ /min
1	Walking, horizontal, treadmill	Normal, 75 kg	4	3.5-4.5	0.7-0.9	39	Carrying 20 kg load				
2			6	5.0-5.5	1.0-1.1	40	Walking, horizontal	70 kg	1.6	3.5	0.7
3			8	9.0-10.1	1.8-1.9	41			3.2	4.5	0.9
4			10	14.6-17.6	2.9-3.5	42			4.8	6.0	1.2
5		Athlete, 63 kg	8	8.0	1.6	43			6.4	9.0	1.8
6			10	11.6	2.3	44	Running, horizontal		8.0	14.1	2.8
7			12	16.1	3.2	45	Walking, grade 36%		0.8	6.0	1.2
8	Walking, grade, 0%	Normal, 70-79 kg	4.2	4.0-4.5	0.8-0.9	46			2.4	15.6	3.1
9	treadmill, +5%			5.5-6.0	1.1-1.2	47	Bicycling, level	70 kg + cycle	8.9	3.0	0.6
10	uphill +10%			7.5-8.0	1.5-1.6	48	and gas-meter = 21 kg		15.1	6.0	1.2
11	+15%			10.0-10.5	2.0-2.1	49	Bicycling, grade 3		21.3	10.0	2.0
12	+20%			12.6-13.1	2.5-2.6	50	Free-wheeling, DH	79 kg + cycle	8.6	2.5	0.5
13	+25%			15.1-16.1	3.0-3.2	51	Cycling, DH, -2%	and gas-meter = 16 kg		2.5	0.5
14	downhill -5%	Normal, 70-79 kg	4.2	3.5-4.0	0.7-0.8	52	DH, -10%		4.0	0.8	
15	-10%			3.5	0.7	53	UH, +2%		6.0	1.2	
16	-15%			3.5	0.7		UH, +10%		17.6	3.5	
17	-20%			4.0-4.5	0.8-0.9		Swimming				
18	-25%			5.0	1.0		Breast stroke, steady state	Excellent swimmer	16 m/min	7.0	1.4
19	Walking, horizontal, hard surface road	68-69 kg plus 9 kg clothing and apparatus	5.5	5.5	1.1	54			32	10.0	2.0
20	grass covered road		5.6	6.5	1.3	55			44	14.6	2.9
21	furrow in field		5.4	7.0	1.4	56			56	20.2	4.0
22	harvested field		5.2	7.0	1.4	57	short sprint, 20-40 m	Good swimmer	60	39 ³	7.8 ³
23	plowed field		5.3	8.0	1.6	58			72	72 ³	14.3 ³
24	harrowed field		5.1	10.5	2.1	59	Crawl, steady state	Excellent swimmer	36	10	1.9
25	hard snow	83 kg	6.0	11.9	2.3	60			58	17	3.3
26			9.1	16.1	3.2	61	short sprint, 20-40 m	Good swimmer	60	23 ³	4.5 ³
27	soft snow	83 + 20 kg ²	3.9	20.7	4.1	62			80	45 ³	9.0 ³
28	Running, horizontal, treadmill; values for Cal. and O ₂ are for work and recovery	74 kg	12	15.1-16.1	3.0-3.2	63			104	124 ³	24.5 ³
29			14	17.6-18.7	3.5-3.7	64	Skiing, horizontal, loose snow, steady state	83 kg	4.16	8.5	1.7
30			16	20.2-21.7	4.0-4.3	65			10.67	15.6	3.1
31			18	24.2-25.8	4.8-5.1	66			14.73	26.2	5.2
32			20	30.3-34.3	6.0-6.8	67	Carrying 20 kg			13.1	2.6
33	Running, horizontal, on track; values for Cal. and O ₂ are for work and recovery	75 kg	19.2	28-31	5.5-6.1	68			4	14.1	2.8
34		74 kg	26.3	66-91	13-18	69	Snow-shoeing, horiz.			15.6	3.1
35		70 kg	28.1	76-167	15-33	70	Carrying 20 kg				
36		72 kg	28.8	106-232	21-46	71	Rowing; assistant also in boat	70 kg	3.2	5.0	1.0
37	Running, grade 8.6%	70 kg	9.3	13.1	2.6	72			5.6	10.0	2.0
38			11.3	16.2	3.2	73	Skating, smooth ice	70 kg	14.5	8.0	1.6
						74			20.9	13.5	2.7

/1/ At the resting level or for light work a satisfactory conversion factor is one liter of oxygen = 4.9 Calories, but work requiring 1.5-2 liters of oxygen per minute will use glycogen, and a factor of one liter O₂ = 5.05 Calories is considered more valid. /2/ Extra load carried. /3/ Work plus recovery.

317. MOTOR PERFORMANCES: ANIMALS

Part I: MAMMALS

Species	Velocity mi/hr	Remarks	Species	Velocity mi/hr	Remarks
Running					
1 Antelope, prong-horned (<i>Antilocapra americana</i>)	70	Maximum in short burst.	24 Hare, arctic (<i>Lepus groenlandicus</i>)	30-40	Pressed, 3 miles.
2	20-36	Normal gait.	25 Horse, domestic (<i>Equus caballus</i>)	42.3	Running, 440 yards.
3 Ass, Asiatic wild (<i>Equus hemionus</i>)	30	Average, 16 miles.	26	39.1	Running, 1 mile.
4 Bison, American (<i>Bison bison</i>)	30-32	Maximum, pressed.	27	31.1	Trotting, 1 mile.
5 Camel, dromedary (<i>Camelus dromedarius</i>)	9-10	Racing, 115 miles in 12 hr.	28	11.2	Trotting, 100 miles.
6	2	Normal walking, loaded.	29 Kangaroo, great (<i>Macropus</i> sp)	25	Chased.
7 Caribou, barren ground (<i>Rangifer arcticus</i>)	25+	Average maximum.	30 Mink (<i>Mustela vison</i>)	7-8	Average maximum.
8 Cheetah (<i>Acinonyx jubatus</i>)	65-70	Maximum, 440 yards.	31 Mole, common (<i>Scalopus aquaticus</i>)	1.5	On surface.
9 Chipmunk, least (<i>Eutamias</i> sp)	10	Pressed, 50 yards.	32 Monkey, langur (<i>Presbytis senex</i>)	23+	On ground, 70 yards.
10 Coyote (<i>Canis latrans</i>)	28-43	Maximum, short dash.	33 Moose (<i>Alces americana</i>)	35	Pressed to maximum, 1/4 mile.
11	24	Average, 1 mile.	34 Rabbit, white-tailed jack (<i>Lepus townsendii</i>)	34	50 yards.
12 Deer, white-tailed (<i>Odocoileus virginianus</i>)	49	Maximum, pressed.	35 Rat, Calif. kangaroo (<i>Dipodomys heermanni</i>)	5.4-12	Pressed, 16-52 feet.
13	15-18	Not pressed.	36 Reindeer (<i>Rangifer tarandus</i>)	13.3	Pulling sled, 1.6 miles.
14 Dog, domestic (<i>Canis familiaris</i>)	43	Maximum for saluki.	37 Rhinoceros, black (<i>Diceros bicornis</i>)	20+	Sustained maximum.
15	30-36	Racing greyhound, average	38 Sheep, bighorn (<i>Ovis canadensis</i>)	30	Pressed, 1/4 mile.
16	22	Average, 1 mile, foxhound.	39 Sloth	0.5	
17 Elephant, African (<i>Loxodonta africana</i>)	25	Charging, 120 yards.	40 Squirrel, gray (<i>Sciurus carolinensis</i>)	15	40 or 50 feet.
18 Elk, American (<i>Cervus canadensis</i>)	18	Unhurried, 1 mile.	41 Squirrel, southern flying (<i>Glaucomys volans</i>)	4-5	Maximum.
19 Fox, gray (<i>Urocyon cinereoargenteus</i>)	40	Pressed, 3/4 mile.	42 Swine, domestic (<i>Sus scrofa</i>)	11	
20 Fox, red (<i>Vulpes fulva</i>)	26	Average maximum, 1 mile.	43 Warthog (<i>Phacochoerus aethiopicus</i>)	30	
21 Gazelle, Grant's (<i>Gazella granti</i>)	50+	1/2 mile.	44 Wildebeest (<i>Connochaetes</i> sp)	50+	Maximum, 1/4 mile.
22 Giraffe (<i>Giraffa camelopardalis</i>)	28-32	Pressed.	45 Wolf (<i>Canis lupus</i>)	28-40	Maximum up to 200 yards.
23 Goat, mountain (<i>Oreamnos americanus</i>)	20+	Maximum.	46 Woodchuck (<i>Marmota monax</i>)	10	Maximum, 1 minute.
Species	Distance ft	Remarks	Species	Distance ft	Remarks
Leaping, Horizontal					
47 Antelope, pronghorned (<i>Antilocapra americana</i>)	12-20	Bound at high speed.	58 Mink (<i>Mustela vison</i>)	0.8-1.2	Normal bound.
48 Chipmunk (<i>Tamias striatus</i>)	6	Maximum.	59 Mouse, woodland jumping (<i>Napaeozapus insignis</i>)	10-12	Frightened, maximum leap.
49 Deer, mule (<i>Odocoileus hemionus</i>)	18-25	Effortless bounding.	60	1-3	Normal leap.
50 Dog, domestic (<i>Canis familiaris</i>)	15	Stride, racing whippet.	61 Puma (<i>Felis concolor</i>)	40-47?	Maximum leap.
51 Fisher (<i>Martes pennanti</i>)	40	Descending diagonally.	62 Rabbit, white-tailed jack (<i>Lepus townsendii</i>)	18-21	Maximum bound.
52 Hare, varying (<i>Lepus americanus</i>)	4-10	Normal bounds.	63	6-9	Slow speed hop.
53 Impalla (<i>Aepyceros melampus</i>)	30-40	Estimated maximum.	64 Rat, kangaroo (<i>Dipodomys</i> sp)	9-12	Frightened, maximum leap.
54 Jerboa (<i>Dipus sagitta</i>)	12-15	Estimated maximum.	65 Squirrel, southern flying (<i>Glaucomys volans</i>)	152	Max. diagonal descending glide.
55 Kangaroo, great (<i>Macropus</i> sp)	35	Chased, maximum leap.	66 Squirrel, red (<i>Tamiasciurus hudsonicus</i>)	15-20	Max. diagonal descending leap.
56 Lynx, Canadian (<i>Lynx canadensis</i>)	12-15	Normal maximum leap.	67 Squirrel, gray (<i>Sciurus carolinensis</i>)	2	Normal bound.
57 Marten, American (<i>Martes americana</i>)	3	Normal maximum bound.	68 Weasel, long-tailed (<i>Mustela frenata</i>)	2.5-3.5	Average maximum bound.
Leaping, Vertical					
69 Antelope, pronghorned (<i>Antilocapra americana</i>)	5		77 Mouse, meadow jumping (<i>Zapus hudsonius</i>)	3+	
70 Coyote (<i>Canis latrans</i>)	4	"Spy-hop."	78 Mouse, kangaroo (<i>Microdipodops megacephalus</i>)	1.5	
71 Deer, white-tailed (<i>Odocoileus virginianus</i>)	8	Pressed.	79 Muskrat (<i>Ondatra zibethicus</i>)	2.5	
72 Elk, American (<i>Cervus canadensis</i>)	8	Pressed.	80 Peccary (<i>Tayassu</i> sp)	4	
73 Impalla (<i>Aepyceros melampus</i>)	8	Estimated maximum.	81 Puma (<i>Felis concolor</i>)	10-18?	
74 Jerboa (<i>Dipus sagitta</i>)	3+		82 Rabbit, antelope jack (<i>Lepus alleni</i>)	2.5-5.5	Easy bound.
75 Kangaroo, giant (<i>Macropus</i> sp)	9		83 Rat, large kangaroo (<i>Dipodomys spectabilis</i>)	1.5-2	"Spy-hop."
76 Kangaroo, rat (<i>Bettongia penicillata</i>)	8		84 Squirrel, red (<i>Tamiasciurus hudsonicus</i>)	3	
Species	Velocity mi/hr	Remarks	Species	Velocity mi/hr	Remarks
Swimming					
85 Beaver, American (<i>Castor canadensis</i>)	2	Maximum.	90 Mink (<i>Mustela vison</i>)	1-1.5	Normal.
86 Caribou, woodland (<i>Rangifer caribou</i>)	4	Estimated maximum.	91 Mole, common (<i>Scalopus aquaticus</i>)	0.7	
87 Deer, white-tailed (<i>Odocoileus virginianus</i>)	4+	Estimated maximum.	92 Muskrat (<i>Ondatra zibethicus</i>)	3	Maximum.
88 Dolphin	35-37+	Playing before ship.	93 Porcupine (<i>Erethizon dorsatum</i>)	2+	Cruising.
89 Dolphin, bottle-nosed (<i>Tursiops truncatus</i>)	21	Maximum.	94 Whale, blue (<i>Sibbaldus musculus</i>)	16	Chased.
Flying					
95 Bat	20				

Part II. BIRDS, REPTILES, FISH

Part II. BIRDS, REPTILES, FISH					
Species	Velocity mi/hr	Remarks ¹	Species	Velocity mi/hr	Remarks ¹
Birds: Flying					
1 Blackbird, tricolored (<i>Agelaius tricolor</i>)	46-48	To and from nest.	36 Martin, house (<i>Chelidon urbica</i>)	24-27	Cruising.
2 Bluebird, mountain (<i>Sialia currucoides</i>)	18	Side wind.	37 Meadowlark, western (<i>Sturnella neglecta</i>)	26-40	
3 Bobwhite (<i>Colinus virginianus</i>)	28-49	Normal to frightened.	38 Merganser, American (<i>Mergus merganser a.</i>)	30	1.4 mile, not pressed.
4 Bunting, yellow (<i>Emberiza citrinella</i>)	26-35	Easy flight.	39 Oriole, Bullock's (<i>Icterus bullockii</i>)	28-32	
5 Canvasback (<i>Aythya valisineria</i>)	72†	Air speed, pressed.	40 Osprey (<i>Pandion haliaetus</i>)	20-56	Migrating, 2/3 mile.
6 Catbird (<i>Dumetella carolinensis</i>)	12-16		41 Owl, tawny (<i>Strix aluco</i>)	40-45	Deliberate flight to pressed.
7 Crane, sandhill (<i>Grus canadensis</i>)	31-35	Headwind to calm.	42 Partridge, European (<i>Perdix perdix</i>)	25-35	Normal flight.
8 Crow, American (<i>Corvus brachyrhynchos</i>)	17-35		43 Pelican, brown (<i>Pelecanus occidentalis</i>)	14-26	Maintain 26 mph for 8 miles.
9 Cuckoo, European (<i>Cuculus canorus</i>)	27	Pressing some.	44 Pheasant, ring-necked (<i>Phasianus colchicus</i>)	27-38	
10 Curlew, long-billed (<i>Numenius americanus</i>)	35-55	Normal to maximum, pressed.	45 Pigeon, green (<i>Dendrophasa sp</i>)	44-48	2 miles.
11 Dove, ring (<i>Columba palumbus</i>)	27-51	Easy flight to pressing hard.	46 Pintail (<i>Anas acuta</i>)	49-65+	Pressed (air speed).
12 Eagle, golden (<i>Aquila chrysaetos</i>)	28-120	Migrating to diving.	47 Plover, European golden (<i>Pluvialis apricaria</i>)	60-70	Air speed, chased.
13 Egret, American (<i>Casmerodius albus e.</i>)	17-32	Normal to pressed.	48 Quail, California (<i>Lophortyx californica</i>)	38-58	
14 Falcon, peregrine (<i>Falco peregrinus</i>)	26-180	Cruising to diving.	49 Raven (<i>Corvus corax</i>)	24-40	Normal, to 1300 yards.
15 Flicker, red-shafted (<i>Colaptes cafer</i>)	25-44	Normal to alarmed.	50 Redhead (<i>Aythya americana</i>)	31-55	Cruising to pressed.
16 Gannet (<i>Moris bassana</i>)	25-48		51 Robin (<i>Turdus migratorius</i>)	17-36	
17 Goldfinch, European (<i>Carduelis carduelis</i>)	26	Normal.	52 Rook (<i>Corvus frugilegus</i>)	24-45	
18 Goose, Canada (<i>Branta canadensis m.</i>)	20-60	Cruising to pressed (air speed).	53 Sandpiper, western (<i>Ereunetes mauri</i>)	44-55	Level flight to maximum air speed.
19 Grackle, bronzed (<i>Quiscalis versicolor</i>)	20-30		54 Shoveller (<i>Spatula clypeata</i>)	25-53+	
20 Grouse, ruffed (<i>Bonasa umbellus</i>)	30-51	Flying in brush and to cover..	55 Shrike (<i>Lanius ludovicianus</i>)	22-45	
21 Gull, herring (<i>Larus argentatus</i>)	12-36	Easy flight.	56 Sparrow, house (<i>Passer domesticus</i>)	24-35	
22 Harrier, American marsh (<i>Circus cyaneus</i>)	21-38	Migrating, 2/3 mile.	57 Starling, European (<i>Sturnus vulgaris</i>)	18-51	Calm to pressed.
23 Hawk, Cooper's (<i>Accipiter cooperii</i>)	21-55	Migrating, 2/3 mile.	58 Stork, white (<i>Ciconia ciconia</i>)	48	Migrating, air speed.
24 Heron, great blue (<i>Ardea herodias</i>)	18-36	Cruising to pressed.	59 Swallow, barn (<i>Hirundo rustica</i>)	20-46	
25 Hummingbird, ruby-throated (<i>Archilochus colubris</i>)	45-55	Easy flight.	60 Swan, whistling (<i>Cygnus columbianus</i>)	18-55	Cruising to pressed (air speed).
26 Ibis, white-faced glossy (<i>Plegadis guarauna</i>)	30-33	Cruising.	61 Swift	68+	Passed plane at this air speed.
27 Jay, blue (<i>Cyanocitta cristata</i>)	20		62 Teal, European (<i>Anas crecca</i>)	44-68	Cruising to pressed (air speed).
28 Kestrel (<i>Falco tinnunculus</i>)	35-44	Easy flight.	63 Tern, common (<i>Sterno hirundo</i>)	13-29	Cruising.
29 Killdeer (<i>Charadrius vociferus</i>)	25-55		64 Thrasher, sage (<i>Oreoscoptes montanus</i>)	22-29	Cruising.
30 Kingfisher, belted (<i>Megasceryle alcyon</i>)	36	Easy flight.	65 Thrush, song (<i>Turdus philomelus</i>)	31	Pressed.
31 Lark, horned (<i>Eremophila alpestris</i>)	17-54		66 Titmouse, blue (<i>Parus caeruleus</i>)	21	Tree to tree, 40 yards.
32 Linnet (<i>Carduelis cannabina</i>)	26-36	Short to long flight.	67 Turkey, wild (<i>Meleagris gallopavo</i>)	55	Pressed, 1 mile.
33 Loon, common (<i>Gavia immer</i>)	53	5 miles.	68 Vulture, turkey (<i>Cathartes aura</i>)	15-34	Normal to migrating, 2/3 mile.
34 Magpie (<i>Pica pica</i>)	19-35	Normal to pressed.	69 Warbler, willow (<i>Phylloscopus trochilis</i>)	24-27	Pressed.
35 Mallard (<i>Anas platyrhynchos</i>)	26-60	Normal to pressed (air speed).	70 Woodcock (<i>Philohela minor</i>)	5-13	
Birds: Running					
71 Avocet (<i>Recurvirostra americana</i>)	8	Pressed, 50 feet.	77 Ostrich (<i>Struthio camelus</i>)	50+	1/2 mile.
72 Chicken, domestic (<i>Gallus gallus</i>)	9		78 Partridge, chuker (<i>Alectoris graeca</i>)	12-18	12 mph for 20 yards.
73 Curlew, long-billed (<i>Numenius americanus</i>)	8-10	75 yards, pressed.	79 Pheasant, ring-necked (<i>Phasianus colchicus</i>)	8-21	30-200 yards.
74 Emu (<i>Dromiceius novaehollandiae</i>)	35-40	Not maximum.	80 Quail, California (<i>Lophortyx californica</i>)	12-15	Chased.
75 Grouse, sage (<i>Centrocercus urophasianus</i>)	2	Before car, 30 feet.	81 Road runner (<i>Geococcyx californianus</i>)	10-22	Pressed, 50-300 yards.
76 Killdeer (<i>Charadrius vociferus</i>)	5	30 feet.	82 Sparrow, vesper (<i>Pooecetes gramineus</i>)	9	Upgrade, 100 feet.
Reptiles: Running			Species		
83 Lizard, six-lined	18	Not pressed, 1 minute.	Distance		
84 Red racer	3.6	Maximum.	Remarks		
85 Sidewinder	2.0	Maximum.	Fish: Leaping, Horizontal		
86 Snake, coral king	0.7	Maximum.			
Fish: Swimming			Fish: Leaping, Vertical		
87 Carp	0.9		93 Flying fish, biplane (<i>Cypselurus sp</i>)	650-1300	Horizontal glide.
88 Flying fish, biplane	22-40	Maximum in pre-flight taxi.	94 Flying fish, biplane (<i>Parexocoetus sp</i>)	7-25	Horizontal glide.
89 Mackerel-like fish	30	Cruising.	95 Flying fish, monoplane (<i>Exocoetus sp</i>)	33-67	Horizontal glide.
90 Perch	1.3		96 Flying fish, primitive (<i>Oxyporhamphus sp</i>)	17-27	Horizontal glide.
91 Pike	10		Fish: Leaping, Vertical		
92 Salmon	7		97 Atherine, fresh-water	10-20x ²	
			98 Flying fish, monoplane (<i>Exocoetus sp</i>)	7-13	High point of glide.
			99 Mullet, striped	10-20x ²	
			100 Tuna	Several	

/1/ First part of remark covers first figure of range in velocity column, second part of remark covers second figure. /2/ Times length of fish.

318. PHYSICAL TRAINING, EFFECTS: MAN

Changes in Physical Capacity					Physiological Effects				
Test	Subjects	Training		Gain %	Test	Subjects	Training		Gain %
		Before	After				Before	After	
1 Pushups, max. no.	Men	18.1	21.3	17.6	37 Basal O ₂ consumption, ml/m	Men	228	208	9
2 of times	Women	10.7	15.6	46	38 O ₂ cost in running	Men	13, 57	14, 13	4
3 Pullups, max. no.	Men	10.0	10.8	8	39 Respiratory efficiency	Men	55.3	46.1	17
4 of times	Women	5.5	8.7	59	40 Resp. quotient	Men	0.82	0.93	
5 Situps, max. no.	Men	38.4	51.1	34	41 Resp. rate, exercising	Runners ¹	44	48	
6 of times	Women	19.9	32.2	63	42 Resp. min. volume	Men	6.23	5.69	9
7 Shoulder strength, push, lb	Women	48.7	53.2	9.2	43 Vital capacity	Runners ¹	4.74	5.36	
8 pull, lb	Women	44.6	46.8	5.1	44 Alveolar pCO ₂ , mmHg	Men	41.5	41.3	
9 Muscular strength	Weight lifters	102.7	107.7	4.6	45 Alveolar pO ₂ , mmHg	Men	100.3	98.1	
	Non-lifters	101.5	104.3	2.7	46 Blood gas capacity, vol. % O ₂	Men	19.83	20.18	
10 Knee extension, kg	Trained limb	24.1	30.9	28.2	47 Hemoglobin, g/100ml	Men	14.8	15.2	
11	Untrained limb	24.5	33.6	37.0	48 Red blood cells, millions	Men	4.62	4.73	
12 Hand curl, kg	Trained limb	9.8	12.6	28.2	49 Hematocrit	Men	44.1	46.0	
13	Untrained limb	9.6	11.8	22.6	50 Alkaline reserve, CO ₂	Men	47.8	46.6	
14 Finger ergograph,	Trained limb	13.2	26.1	97.4	51 combining power, vol. %	Runners ¹	48.0	48.1	
15 total work, kg	Untrained limb	10.9	16.6	52.7	52 Alk. res. after running, mM/L	Men	11.8	10	
16 Finger ergograph, no. times	Men	276	858	212	53 Exercise pulse rate	Men	151	146	
17 Left arm performance	Right arm trained	53.5	79.8	49.2	54	Runners ¹	134	111	
18	Right arm untrained	53.2	58.2	9.4	55 Pulse after 30 sec recovery	Runners ¹	115	77	
19 Shot put, 8 lb	Weight lifters	33.3	36.3	9.0	56 Resting pulse	Men	66.8	61.8	
20	Non-lifters	31.2	31.6	1.3	57 Resting blood pressure	Men	114/65	113/67	
21 Shot put, 12 lb	Weight lifters	27.2	29.5	8.5	58 Stroke volume, ml	Men	82	80	-2.5
22	Non-lifters	25.1	25.7	2.4	59 Cardiac output, liters/hr	Men	4.62	4.71	-2
23 Broad jump, standing, ft	Weight lifters	7.5	7.8	4.0	60 Systolic heart volume, ml	Men	565	469	-17
24	Non-lifters	7.1	7.1	0	61 Heart diameter, cm	Men	11.9	10.9	-8
25 Running, 60 yd, sec	Weight lifters	7.9	7.6	3.8	62 Heart volume, ml	Men	785	930	
26	Non-lifters	8.1	8.1	0		Women	560	790	
27 Running, 300 yd, sec	Men, 18-22 yr	44.3	42.7	3.6	64 Blood volume, ml	Men	5250	6580	
28 Running, 5 min, yd	Men	1490	1510	1.3	65	Women	4070	5670	
29 Obstacle course, sec	Men	24.7	22.0	10.9	66 Leukocytes, thousands	Men	5.96	6.1	
30 Muscle endurance	Weight lifters	220.4	267.8	21.0	67 Plasma chloride, mEq	Men	103.6	105.8	
31	Non-lifters	189.5	235.9	24.5	68 Plasma nitrogen, g/L	Men	10.3	10.8	
32 Endurance	Women	25.2	30.5	21	69 Blood sugar, max., mg/100ml	Men	127	134	
33 Walking efficiency	Men	15.3	16.9	10.4	70 Blood lactate, max., mg/100ml	Men	114	134	
34 Max. work, treadmill, kgM	Men	3786	6046	59.6	71 Blood lactate, exercise ² , 100ml	Men	146	192	
35 Work per liter O ₂ debt	Men	484	737	52.2	72	Runners ^{1,3}	19.1	13.4	

/1/ Champion male runners; values before training are not necessarily for those men for whom values are given after training. /2/ After strenuous exercise. /3/ During mild exercise.

319. PHYSIOLOGICAL CHANGES DURING EXERCISE, EFFECT OF AGE: MAN

Values are results obtained with various age-groups of healthy, well-trained subjects during maximum physiological activity (treadmill or bicycle). Values in parentheses are estimate "c" of the 95% range (cf. Introduction).

Specifications	4-6 yr	7-9 yr	10-11 yr	12-13 yr	14-15 yr	16-18 yr	20-33 yr
1 Body height, cm ♂	113.5(107-128)	135.0(125-143)	145.4(132-157)	154.4(139-169)	171.8(150-188)	176.9(165-187)	176.7(165-188)
2 " ♀	111.6(108-114)	132.0(121-142)	140.6(129-148)	158.5(150-175)	164.9(156-173)	167.7(162-176)	165.8(155-175)
3 Body weight, kg ♂	20.8(16.0-27.8)	30.7(25.1-36.5)	36.5(31.1-44.7)	43.6(31.8-60.6)	59.5(40.6-76.2)	64.1(45.2-73.4)	70.4(61.7-86.6)
4 " ♀	18.4(17.4-21.9)	27.2(20.6-33.0)	32.5(27.0-37.4)	46.7(39.6-60.5)	56.0(46.2-67.1)	57.3(50.5-63.7)	60.3(50.0-72.8)
5 Vital capacity ¹ , L ♂	2.21(1.84-2.51)	2.65(2.24-3.25)	3.22(2.52-4.33)	4.55(2.78-6.57)	5.17(3.20-6.48)	5.68(4.17-7.26)	5.68(4.17-7.26)
6 " ♀	1.95(1.69-2.24)	2.30(1.88-2.63)	3.25(2.52-4.01)	3.74(2.94-4.32)	4.14(3.24-5.04)	4.28(3.15-5.76)	4.28(3.15-5.76)
7 Max. heart rate ♂	203(188-214)	208(191-220)	211(200-227)	205(175-237)	203(178-222)	202(194-220)	194(171-212)
8 " ♀	204(176-214)	211(194-223)	209(192-220)	207(188-222)	202(192-217)	206(188-214)	198(184-225)
9 Max. O ₂ intake ² , L/min ♂	1.01(0.77-1.30)	1.75(1.40-2.01)	2.04(1.78-2.32)	2.46(1.79-3.40)	3.53(2.59-4.47)	3.68(2.84-4.35)	4.11(3.30-5.09)
10 " ♀	0.88(0.74-0.94)	1.50(1.21-1.79)	1.70(1.48-1.94)	2.31(2.01-2.72)	2.58(2.02-3.31)	2.71(2.25-3.08)	2.90(2.41-3.40)
11 Max. O ₂ intake ² , L/min ♂	49.1(43.2-57.6)	56.9(51.8-62.7)	56.1(51.1-61.5)	56.5(53.0-61.9)	59.5(54.8-63.7)	57.6(51.0-62.4)	58.6(51.1-67.4)
12 " ♀	47.9(42.4-52.2)	55.1(49.3-58.8)	52.4(46.4-56.1)	49.8(45.0-53.5)	46.0(42.5-52.5)	47.2(42.8-51.2)	48.4(43.2-59.6)
13 Max. pulmonary ventilation ¹ , L/min ♂	39.8(30.9-43.5)	61.8(44.1-75.2)	70.5(50.0-77.5)	75.2(58.1-105.0)	112.9(84.5-140.3)	110.3(79.6-139.3)	122.0(91.5-160.3)
14 " ♀	33.9(31.0-38.9)	57.3(48.2-67.6)	61.1(46.2-80.9)	79.9(65.5-102.6)	87.9(68.4-100.7)	93.8(73.6-119.1)	92.2(74.4-114.8)
15 Max. respiratory rate ♂	70.4(63-90)	67.0(55-83)	57.5(32-77)	54.1(31-68)	52.9(39-68)	44.7(28-60)	39.9(27-59)
16 " ♀	66.4(56-81)	67.1(54-94)	61.3(51-82)	54.4(41-88)	51.6(40-58)	51.2(44-60)	46.0(28-63)
17 Max. respiratory depth, L ♂	0.60(0.43-0.87)	1.05(0.72-1.25)	1.33(1.12-1.62)	1.59(1.02-2.54)	2.52(1.62-3.26)	2.77(1.68-3.40)	3.05(2.26-4.72)
18 " ♀	0.52(0.40-0.58)	0.91(0.64-1.22)	1.05(0.85-1.36)	1.64(1.28-2.54)	1.87(1.34-2.41)	1.95(1.43-2.28)	2.10(1.64-3.29)
19 Max. blood lactic acid, mg/100ml ♂	56.3(33-76)	82.0(60-110)	84.0(50-125)	79.1(45-143)	90.4(74-113)	104.9(83-138)	112.0(71-158)
20 " ♀	60(51-69)	76.5(64-85)	82.2(56-116)	97.6(76-119)	100.5(73-145)	110.2(77-144)	103.6(69-134)

/1/ Body temperature, pressure; saturated. /2/ Standard temperature, pressure, density.

320. PHYSIOLOGICAL EFFECTS, SUBMAXIMAL WORK: MAN

Values are for young adults (20-30 yr) doing submaximal work on the bicycle ergometer. Values in parentheses are estimate "b" of the 95% range (cf. Introduction).

Sex	Work Intensity kg m/min	O ₂ Intake ¹ L/min	Net Efficiency %	O ₂ Intake [% of Max Intake] %	Heart Rate	Ventilation ² L/min	Ventilation ² per L O ₂ Intake	Ventilation [% of Max Vent.] %
1 ♀	600	1.48(1.32-1.64)	22.5(19.2-25.8)	52(41-63)	138(115-161)	34.7(24.9-44.5)	23.4(18.5-28.3)	39(27-51)
2 ♀	900	2.06(1.88-2.24)	23.1(20.9-25.3)	73(60-86)	168(143-193)	50.6(37.3-63.9)	24.5(19.2-29.8)	56(38-74)
3 ♂	900	2.09(1.90-2.28)	23.4(21.1-25.7)	50(42-58)	128(105-151)	41.9(32.1-51.7)	20.1(15.7-24.5)	34(23-45)
4 ♂	1200	2.67(2.44-2.90)	23.7(21.4-26.0)	64(51-77)	148(125-171)	55.2(41.1-69.3)	20.6(15.8-25.4)	45(30-60)
5 ♂	1500	3.33(3.00-3.66)	23.3(21.0-25.6)	79(67-91)	167(144-190)	70.9(55.3-86.5)	21.1(16.9-25.3)	58(39-77)

/1/ Standard temperature, pressure, density. /2/ Body temperature, pressure, saturated.

321. PHYSIOLOGY OF NEWBORN: MAN

Values are to be considered as "estimates" because the newborn period is not a time when measurements are likely to be "normal." Ranges of values obtained from normal infants vary widely with the day of life and even with the hour within the first day. Variation will also depend on whether the cord is clamped early or late and whether the infant is full term or premature. The relatively high immunity to the usual infectious diseases of infants during the first 6-12 months of age is generally attributed to immune bodies obtained in utero by placental passage.

Part I: CHEMICAL AND PHYSICAL PROPERTIES

Variable	Age ¹		Variable	Age ¹	
	Birth	One Week		Birth	One Week
Blood			Miscellaneous		
1 Calcium serum, mg/100 ml	11.3(7.3-17)	10.5(7.5-13.9), IV-VII	31 Blood pressure, systolic/diastolic, mm Hg	80/40	92/50
2 Cholesterol, ester, plasma, mg/100 ml	82(50-130), I	140(100-190), V-XI	32 Bleeding time, min (Duke's method)	(1.5-2.5)	
3 Cholesterol, free, plasma, mg/100 ml	32(22-44), I	50(40-70), V-XI	33 Cardiac output, ml/min	528(313-696)	580(438-855)
4 Citric acid, serum, mg/100 ml	(3-6)		34 Circulation time, umbilical vein to lip, sec ³	4.8(3.1-7)	
5 Fat, neutral, plasma, mg/100 ml	80(10-150), I	175(90-270), V-XI	35 Circulation time, sinus venosum to lip, sec ³	4.4(3.3-5.8)	
6 Hemoglobin, capillary, g/100 ml	19.9(14-27)	19.6(16.2-25.5)	36 Clotting time, normal plasma, min	4	4
7 Hemoglobin, venous or cord, g/100 ml	17(13-24)	19(15-25)	37 Clotting time, platelet free plasma, min	5	7
8 Iron, serum, µg%	(30-120)	114(70-200), VI	38 Erythrocytes, capillary, millions/cu mm	5.6(4-7.5)	
9 Lipids, total, plasma, mg/100 ml	221(120-320), I	470(300-650), V-XI	39 Erythrocytes, venous or cord, millions/cu mm	4.8(3.8-6)	5.3(3.6-7.6)
10 Nitrogen, blood urea, mg/100 ml	17(13-19), III	14(13-15)	40 Erythrocytes, corpuscular volume, cu µ	113(90-124)	107(90-124)
11 Nitrogen, non-protein, mg/100 ml	54(44.5-61), III	40(26.5-48)	41 Erythrocytes, nucleated, % nucleated cells	7(0-15)	> 1%, III
12 Phosphatase, serum, Bodansky units	7(4.5-10), I-III	9(6.5-11), IV-XIV	42 Hematocrit, venous	53(45-60)	55(42-66)
13 Phosphatides, plasma, mg/100 ml	27(0-94), I	100(20-200), V-XI	43 Platelets, capillary, thousands/cu mm	227(140-290)	233(160-320)
14 Phosphorus, serum, mg/100	5.5(4.2-8)	5.9(3.5-7.6), IV-VII	44 Prothrombin time, venous, % of normal	76(37-100)	86(69-100), V
15 Protein, total, serum, g/100 ml ²	6(5.0-7.5)		45 Pulse, beats/min	112(96-130), I	119(103-133)
Bone Marrow			46 Respiration rate, breaths/min	25(14-34)	28(18-40)
16 Leukocytes, total, thousands/cu mm	186(54-358)	134(53-327), VIII	47 Reticulocytes, % total erythrocytes	4.4(2.5-6.5)	1.1(0.1-4.5)
Differential cell count, % of total			48 Tidal air, ml	(15-25)	(15-25)
17 Basophil	0	0, VIII	49 Urine, pH	5.7(5.2-6.3), I	6.4(5.2-7.2)
18 Eosinophil	2	1.7, VII	50 Urine, specific gravity ⁴	1.012(1.008-1.018), I	1.009(1.005-1.011)
19 Erythroblast	1(0-5.2)	0.5(0-2.6), VIII	51 Volume, blood ⁵ , % body wt	9.4(7.2-12.8)	9.6(8-13.8), III
20 Erythrocyte, nucleated, total	31.9(16.4-49)	11.6(5-23), VIII	52 Volume, blood ⁶ , % body wt	12.2(8-14.9)	12.1(8.2-16.2), III
21 Lymphocyte	3.8	6.2, VIII	White Blood Cells		
22 Megakaryocyte	0.1	0.1, VIII	53 Leukocytes, total, thousands/cu mm blood	18(9-30)	12(5-21)
23 Megaloblast	0.1	0.1, VIII	Differential leukocyte count, % of total		
24 Myeloblast	0.8	1.5, VIII	54 Basophil	0.1(0-0.6)	0.05(0-0.25)
25 Myelocyte, eosinophilic	0.6	0.6, VIII	55 Eosinophil	0.4(0.02-0.9)	0.5(0.07-1.1)
26 Myelocyte, neutrophilic	16.3(7-29.6)	19.7(8-34), VIII	56 Lymphocyte	5.5(2-11)	5(2-17)
27 Neutrophil, non-segmented	33.9(16.4-46)	43.5(15.4-61), VIII	57 Monocyte	1.1(0.4-3.1)	1.1(0.3-2.7)
28 Neutrophil, segmented	7(0-17)	10.4(10-29.4), VIII	58 Neutrophil, banded	1.6	0.8
29 Normoblast	30.8(16.2-44.6)	11(4.4-22.4), VIII	59 Neutrophil, segmented	9.4	4.7
30 Reticulum cell	0	0.1, VIII	60 Neutrophil, total	11(6-26)	5.5(1.5-10)

/1/ Roman numerals indicate age in days when age varies from column headings. /2/ Cord blood. /3/ Fluorescein. /4/ RENAL FUNCTION TESTS. I. Glomerular filtration of H₂O: (a) Inulin Clearance (C_{IN}) for infants 6-30 da of age = 30-50% of adult value; C_{IN} = 48 ml/min/1.73 sq m Body Surface Area (BSA). (b) Creatinine Clearance/Inulin Clearance (C_{CR}/C_{IN}) = 1.00(0.86-1.30). II. Effective Renal Plasma Flow: p-Aminohippurate (PAH) or Diodrast at low (0.5-3 mg/100 ml) plasma concentration = 20-40% of adult value or 135-270 ml/min/1.73 sq m BSA. III Maximal Rate of Tubular Excretion: PAH or Diodrast at high (50-100 mg/100 ml) plasma concentration = 15-40% of adult value or 11.5-30.8 mg/min/1.73 sq m BSA. IV. Maximal Rate of Tubular Reabsorption: Glucose Clearance at high (up to 300 mg %) plasma concentration = 10-30% of adult value or 30-100 mg/min/1.73 sq m BSA. V. Urea clearance = 1.00 ml/min or 7.7 ml/min/1.73 sq m BSA when blood urea nitrogen (BUN) = 19(12-26) mg/100 ml, normal value. Maximal clearance, when BUN = 34(23.4-34.6) mg/100 ml, = 2 ml/min or 14.4 ml/min/1.73 sq BSA. /5/ Early clamped cord. /6/ Late clamped cord.

Part II: ORGAN AND BODY WEIGHTS AT GESTATION INTERVALS

Organ	Interval (days) between First Day of Last Menstrual Period and Delivery							
	167	195	217	248	258	272	279	287
	250-750	750-1250	1250-1750	1750-2250	2250-2750	2750-3250	3250-3750	3750-4250
Body Weight, g								
Organ Weights, g								
1 Adrenals	2.5	3.3	4.3	5.3	6.9	7.6	9.3	10.5
2 Brain	82.8	160.6	226.3	289.2	332.6	390.9	429.6	456.0
3 Heart	4.6	7.6	10.8	14.5	17.9	20.1	21.7	25.4
4 Kidneys	5.3	9.7	13.6	18.3	21.1	23.6	26.6	29.3
5 Liver	31.5	49.2	66.3	87.9	105.8	140.4	151.5	185.1
6 Lungs	15.0	25.2	33.7	44.2	49.5	54.7	59.4	64.0
7 Pancreas	0.6	1.2	1.6	2.1	2.8	3.4	3.6	3.9
8 Spleen	1.0	2.1	4.0	5.8	7.6	9.7	11.1	12.2
9 Thymus	1.4	3.1	5.1	8.5	9.3	9.9	10.8	15.3
10 Thyroid	0.5	4.1	1.1	1.4	1.8	1.8	2.4	2.9

322. PHYSIOLOGICAL VARIABLES: MAN

Values are for males only unless otherwise indicated. Ranges in parentheses on Lines 1-39 conform to estimates "b," and those on Lines 43-46 to "d" of the 95% range (cf Introduction). Differences between values presented here and those in other tables giving more detailed data on one or more of the variables may be attributed to the differences in the sample of "normal" subjects studied by different investigators. The purpose of this table is to indicate the change (if any) of a variable with age, rather than to present a set of "standard values" for each age group.

Variable	Age Group, yr					
	20-29	30-39	40-49	50-59	60-69	70-79
1 Plasma volume, ml/kg body weight	42.3(31.1-53.5)	45.5(34.7-56.3)	42.3(36.3-48.3)	50.8(35.6-66.0)	46.6(32.2-61.0)	47.2(34.4-60.0)
2 Total blood volume, ml/kg body weight	77.3(61.1-93.5)	81.9(65.9-97.9)	73.5(61.3-85.9)	86.1(67.3-104.9)	78.3(58.1-98.5)	80.7(58.7-102.7)
3 Plasma vitamin A, µg/100 ml			47.6(28.6-66.6)	55.0(16.0-77.0)	49.9(22.7-77.1)	47.1(17.9-76.3)
4 Plasma β-carotene, µg/100 ml			126.7(42.7-210.7)	128.3(43.3-213.3)	111.0(22.0-200.0)	106.0(28.2-183.8)
5 Blood pH, capillary serum, 38°C	7.40(7.34-7.46)	7.38(7.33-7.45)	7.38(7.32-7.44)	7.38(7.34-7.42)	7.38(7.34-7.42)	7.37(7.33-7.41)
6 Total blood CO ₂ content, capillary, mM/L	22.8(20.1-25.5)	22.8(19.9-25.7)	22.6(19.6-25.6)	22.3(18.8-25.8)	22.3(18.2-26.4)	22.3(19.4-25.2)
7 CO ₂ tension, arterial blood, mm Hg	44.8(38.3-51.3)	45.2(38.3-52.1)	46.1(38.1-54.9)	45.0(36.2-53.8)	45.3(36.5-54.1)	45.8(38.9-52.7)
8 Serum bicarbonate content, arterial, mM/L	26.5(23.2-29.8)	26.5(23.2-29.8)	26.8(22.4-31.2)	26.0(21.9-30.1)	26.2(21.5-30.9)	25.8(22.3-29.3)
9 Cell volume, % red cells	47(43-51)	47(41-53)	48(36-60)	44(36-52)	45(39-51)	43(35-51)
10 Blood non-protein nitrogen, mg/100 ml			27.2(18.4-36.0)	27.2(19.2-35.2)	27.7(20.7-34.7)	28.5(18.5-28.5)
11 Blood urea nitrogen, mg/100 ml	9.7(4.7-14.7)	10.7(3.5-17.9)	10.6(4.4-16.8)	12.3(6.5-18.1)	13.5(6.3-20.7)	12.9(6.5-19.3)
12 Blood glucose, venous, mg/100 ml	82.1(68.9-95.3)			78.9(54.9-102.9)	79.0(62.0-96.0)	79.6(67.2-92.0)
13 Thiocyanate space (extracellular H ₂ O), L/sq m body surface area			17.0(10.6-23.4)	16.8(11.4-22.2)	16.3(12.3-20.3)	16.1(10.5-21.7)
14 Antipyrine space (total body H ₂ O), L/sq m body surface area			34.6(22.0-47.2)	33.1(20.9-45.5)	31.9(23.1-40.7)	30.2(20.4-40.0)
15 Heart rate, per min	77(52-102)	72(48-96)	70(50-90)	70(52-88)	63(43-83)	66(44-88)
16 Eye, minimum light threshold, 30 min dark adaptation, log µLamberts	2.62(2.08-3.16)	2.67(1.79-3.55)		2.84(2.06-3.62)	3.16(2.22-4.10)	3.85(1.63-6.07)
17 Eye, pupil diameter (in light), mm	5.11(3.70-6.52)	4.64(3.27-6.01)	4.09(2.48-5.70)	3.77(2.20-5.34)	3.48(1.89-5.07)	3.52(2.15-4.89)
18 Eye, pupil diameter (in dark), mm	7.42(6.15-8.69)	6.72(4.96-8.48)	5.91(3.85-7.97)	5.89(3.75-8.03)	4.78(2.70-6.86)	5.10(3.53-6.67)
Kidney function						
19 Tm glucose, mg/min/1.73 sq m body surface area	358.7	333.6(221.2-446.0)	315.1(224.7-405.5)	308.2(178.2-438.2)	260.2(131.0-389.4)	239.3(146.5-332.0)
20 Inulin clearance, ml/min/1.73 sq m B.S.A.	122.8(90.0-155.8)	115.0(93.4-136.6)	121.2(74.6-167.8)	99.3(70.1-128.5)	96.0(45.0-147.0)	89.0(49.2-128.8)
21 Diodrast clearance, ml/min/1.73 sq m B.S.A.	613.5(464.3-762.7)	649.3(414.7-883.9)	573.8(350.6-797.0)	500.4(326.4-674.4)	442.1(281.5-602.7)	354.0(187.2-520.5)
22 PAH clearance, ml/min/1.73 sq m B.S.A.		615.2(409.2-821.2)	511.8(289.0-734.6)	460.4(196.6-724.2)	429.7(244.7-614.7)	292.8(189.0-396.6)
23 Urea clearance, ml/min/1.73 sq m B.S.A.	63.1(30.7-95.5)	60.6(36.4-84.8)	64.6(42.4-86.8)	57.7(33.5-81.9)	46.9(26.5-67.3)	48.3(22.7-73.9)
24 Tm diodrast, mg/inulin/1.73 sq m B.S.A.	54.6(35.6-73.6)	51.0(33.8-68.2)	49.9(30.3-69.5)	45.3(32.8-58.0)	44.5(26.3-62.7)	39.1(24.5-53.7)
25 Tm PAH, mg/min/1.73 sq m B.S.A.		90.6(55.4-125.8)	83.4(50.8-116.0)	74.0(39.2-108.8)	67.2(40.9-93.5)	59.0(35.6-82.4)
26 Conduction velocity of ulnar nerve, m/sec	57.7(37.1-78.3)	58.8(45.1-72.5)	55.6(36.0-75.2)	53.6(36.9-70.3)	52.0(33.5-66.9)	52.6(32.0-73.2)
27 Basal metabolism, cal/sq m/hr			35.7(28.1-43.3)	34.5(25.7-43.3)	33.0(25.9-40.1)	32.6(25.3-39.9)
28 Oxygen uptake, ml/sq m/min			123.5(94.9-152.1)	121.9(86.2-157.6)	112.9(87.4-138.4)	113.1(87.6-138.6)
29 CO ₂ elimination, ml/sq m/min			99.7(81.1-118.3)	98.9(75.0-122.8)	93.4(72.0-114.8)	90.5(68.4-112.6)
30 Ventilation volume, L/sq m/min			3.97(2.62-5.32)	4.03(2.70-5.36)	3.93(2.26-5.60)	4.13(2.78-5.48)
31 Cardiac output (cardiac index), L/sq m/min	3.72(2.04-5.40)	3.54(1.64-5.44)	2.96(1.46-4.46)	2.78(1.74-3.82)	2.58(1.52-3.64)	2.54(1.46-3.62)
32 Stroke index, ml/beat/sq m	48.9(30.7-67.1)	49.4(25.8-73.0)	43.3(24.9-61.7)	40.3(23.3-57.3)	41.5(24.3-58.7)	39.3(20.1-58.5)
33 Circulation time, arm to arm, sec	12.0(7.8-16.2)	13.5(7.9-19.1)	13.7(9.3-18.1)	13.9(7.5-20.2)	15.0(10.0-20.0)	14.9(8.5-21.3)
Pulmonary function						
34 Resting tidal volume, ml/sq m	301(183-419)	297(155-438)	315(123-507)	338(184-492)	302(176-428)	305(175-432)
35 Vital capacity, supine, L/sq m B.S.A.	2.37(1.40-3.33)	2.19(1.36-3.03)	1.94(1.00-2.89)	1.89(1.26-2.53)	1.63(0.76-2.49)	1.40(0.74-2.07)
36 Vital capacity, standing, L/sq m B.S.A.	2.55(1.55-3.55)	2.35(1.52-3.18)	2.14(1.09-3.18)	2.04(0.35-2.73)	1.77(0.93-2.61)	1.51(0.79-2.23)
37 Total lung volume, L/sq m B.S.A.	3.06(1.95-4.17)	2.96(1.90-4.01)	2.88(1.87-3.90)	3.24(2.41-4.07)	2.78(1.82-3.74)	2.83(1.78-3.89)
38 Residual lung volume, L/sq m B.S.A.	0.70(0.29-1.10)	0.79(0.34-1.25)	0.95(0.32-1.59)	1.35(0.42-2.27)	1.15(0.33-1.97)	1.44(0.71-2.17)
39 Maximum breathing capacity (15 sec), L/sq m B.S.A.	69.5(29.5-109.5)	62.3(29.3-95.3)	58.3(19.7-96.9)	43.7(15.7-71.7)	40.4(8.6-72.2)	32.6(9.4-55.8)
Gastric secretion ¹						
40 Total volume, ml	113.5 ± 99.0	109.5 ± 97.7	103.0 ± 95.0	96.3 ± 93.7	92.7 ± 85.5	91.0 ± 79.0
41 Free acidity, ml N/10 NaOH/100 ml	47.0 ± 33.0	47.0 ± 33.0	46.0 ± 33.0	42.6 ± 33.3	38.3 ± 33.5	33.5 ± 33.5
42 Total acidity, ml N/10 NaOH/100 ml	62.5 ± 50.5	61.7 ± 50.5	58.9 ± 50.5	57.6 ± 50.5	54.6 ± 50.5	50.5 ± 50.5
Hearing loss >45 db, % individuals ²						
43 At 440-880 cycles/sec	(0.0-0.1) ± (0.1-0.4)	(0.3-1.1) ± (0.8-1.2)	(1.4-1.7) ± (0.6-2.1)	(2.2-2.6) ± (0.7-4.0)	4.7 ± 1.2	
44 At 1760 cycles/sec	(0.0-0.3) ± 0.3	(0.6-1.2) ± (0.8-1.4)	(2.6-3.6) ± (1.5-2.0)	(6.0-8.4) ± (2.2-3.0)	18.0 ± 9.0	
45 At 3520 cycles/sec	(2.7-5.0) ± (0.3-0.7)	(6.0-7.0) ± (0.6-1.6)	(13-16) ± (2.4-3.0)	(27-30) ± (2.7-7.0)	45.0 ± 12.0	
46 At 7040 cycles/sec	6.7 ± 0.0	7.1 ± 1.4	13.9 ± 3.4	35.1 ± 6.1	49.6 ± 23.6	

/1/ Test meal: 400 ml H₂O and 8 tapioca biscuits. /2/ Samples taken at San Diego County Fair (1948) and World's Fair (Chicago, 1933).

323. EQUATIONS RELATING QUANTITATIVE VALUES WITH BODY WEIGHTS: MAMMALS

Adapted from Adolph, E. F., Science 109:579-585 (1949).

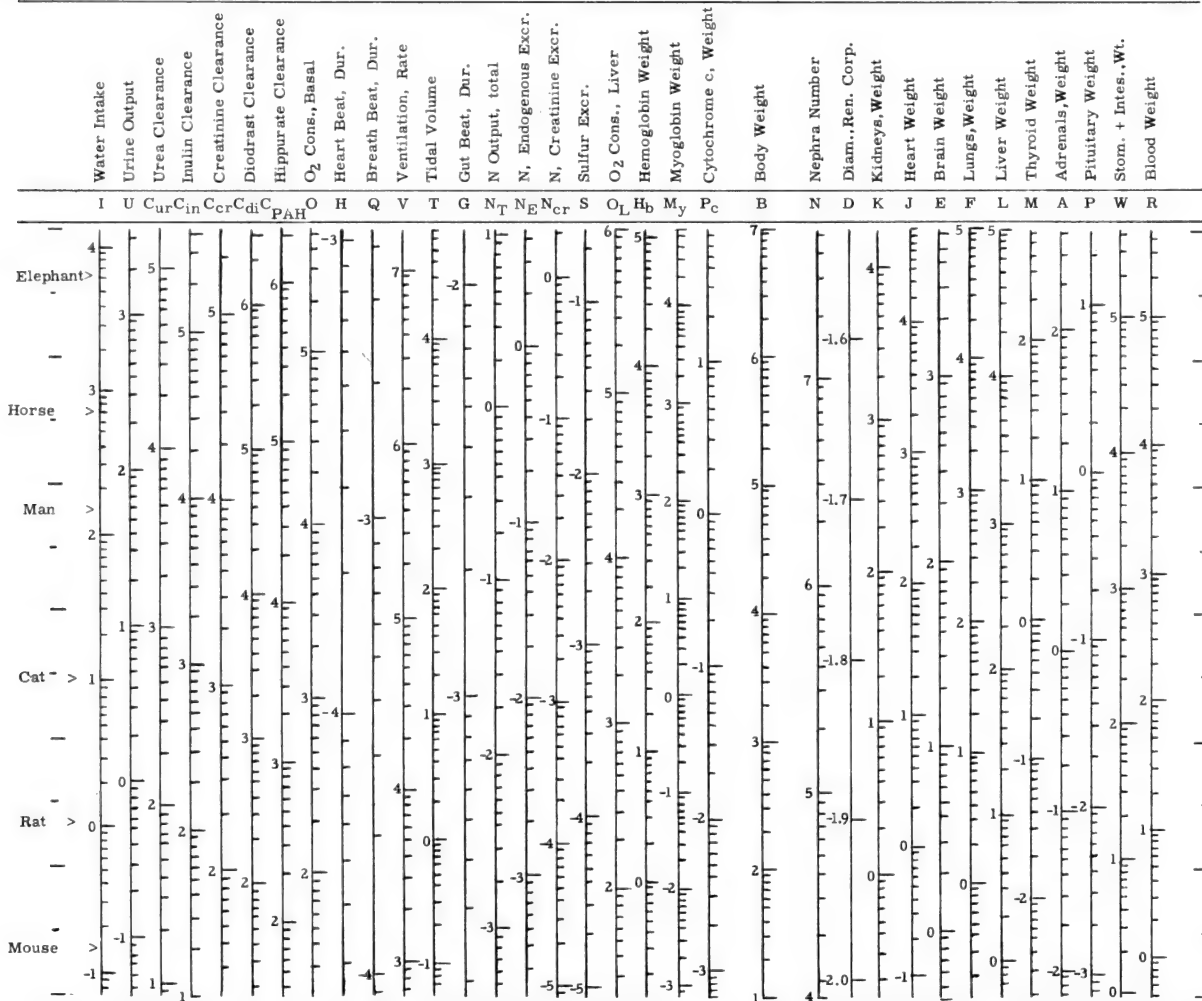
Variable	Symbol	Value	Variable	Symbol	Value
1 Water intake, ml/hr	I	$= .010 B^{.88}$	17 Sulfur output, g/hr	S	$= .000 001 71 B^{.74}$
2 Urine output, ml/hr	U	$= .0064 B^{.82}$	18 O ₂ consum., liver slices, ml STP/hr	O _L	$= 3.3 B^{.77}$
3 Urea clearance, ml/hr	C _{ur}	$= 1.59 B^{.72}$	19 Hemoglobin weight, g	H _b	$= .013 B^{.99}$
4 Inulin clearance, ml/hr	C _{in}	$= 1.74 B^{.77}$	20 Myoglobin weight, g	M _y	$= .000 039 B^{1.31}$
5 Creatinine clearance, ml/hr	C _{cr}	$= 4.2 B^{.69}$	21 Cytochrome weight, g	P _c	$= .000 10 B^{.84}$
6 Diodrast clearance, ml/hr	C _{di}	$= 2.14 B^{.89}$	22 Nephra number	N	$= 2600 B^{.62}$
7 Hippurate clearance, ml/hr	C _{PAH}	$= 5.4 B^{.80}$	23 Diameter, renal corp., cm	D	$= .0081 B^{.08}$
8 O ₂ consum., basal, ml STP/hr	O	$= 3.8 B^{.734}$	24 Kidneys, weight, g	K	$= .0212 B^{.85}$
9 Heartbeat duration, hr	H	$= .000 0119 B^{.27}$	25 Brain weight, g	E	$= .081 B^{.70}$
10 Breath duration, hr	Q	$= .000 047 B^{.28}$	26 Heart weight, g	J	$= .0066 B^{.98}$
11 Ventilation rate, ml/hr	V	$= 120 B^{.74}$	27 Lungs, weight, g	F	$= .0124 B^{.99}$
12 Tidal volume, ml	T	$= .0062 B^{1.01}$	28 Liver weight, g	L	$= .082 B^{.87}$
13 Gut beat duration, hr	G	$= .000 093 B^{.31}$	29 Thyroid, weight, g	M	$= .000 22 B^{.92}$
14 Nitrogen Total output, g/hr	N _T	$= .000 074 B^{.735}$	30 Adrenals, weight, g	A	$= .0011 B^{.80}$
15 Endogenous output, g/hr	N _E	$= .000 042 B^{.72}$	31 Pituitary weight, g	P	$= .000 13 B^{.76}$
16 Creatinine-N output, g/hr	N _{cr}	$= .000 001 09 B^{.90}$	32 Stomach + intestines, weight, g	W	$= .112 B^{.94}$
			33 Blood weight, g	R	$= .055 B^{.99}$

Equations (Derived) Interrelating Quantitative Properties

34 $U = .46 I^{.93} = .0108 C_{ur}^{1.14} = .000,000 19 N^{1.32}$	37 $V = 370,000,000,000,000 H^{2.74} = 4900 T^{.73}$
35 $C_{ur} = .35 C_{PAH}^{.90} = 17,700 N_T^{.98} = 42 K^{.85}$	38 $N_T = .0068 U^{.90} = 5.4 N_{cr}^{.82} = .000,0162 C_{cr}^{1.06}$
36 $O = 1300,000,000,000 H^{2.72} = 11,900 P^{.87}$	39 $O_L = 30 L^{.89} = .81 O^{1.05} = 1290 M_y^{.59}$

324. ALIGNMENT CHART RELATING QUANTITATIVE VALUES: MAMMALS

The characteristics of one animal are read off along a horizontal straight-edge placed at a known value in any one of the variables. Several species chosen at random are indicated on the left at their appropriate scale positions. Ordinates are numbered as exponents of 10; but the subdivisions between ordinates read arithmetically. Thus, the number 1 means 10¹ and the subdivisions above it mean 20, 30, 40, etc. All values are in ml, g, cm, and hr, as shown in Table 323. The lines and scales represent, and are derived from, the equations of Table 323. Adapted from Adolph, E. F., Science 109:579-585 (1949).



325. ANTIMETABOLITES

Table adapted from D. W. Woolley's "A Study of Antimetabolites," John Wiley and Sons, 1952.

Part I: SOME METABOLITES AND THEIR ANTAGONISTIC STRUCTURAL ANALOGS

Metabolite	Analog	Structural Alteration	Biological System Affected
1 Acetic acid	Fluoroacetic acid	F for H	Aconitase
2 Adenine	Benzimidazole and derivatives	2 C for 2 N; side-chain alterations	Microorganisms, animals
	Triazolopyrimidines	N for C	Microorganisms
	Diaminopurine	NH ₂ for H	Bacteria
3 α-Alanine	Glycine	H for CH ₃	Bacteria
4 β-Alanine	β-Aminobutyric acid	CH ₃ for H	Yeast
	Propionic acid	H for NH ₂	Bacteria
	Asparagine	COOH for H; CONH ₂ for COOH	Yeast
5 Arginine	Canavanine	O for CH ₂	Bacteria
6 Aspartic acid	Hydroxyaspartic acid	OH for H	Bacteria
	Aspartophenone	C ₆ H ₅ for OH	Bacteria
7 Ascorbic acid	Glucosascorbic acid	Addition of CHOH and optical inversion	Animals, liver enzymes
8 p-Aminobenzoic acid	Sulfanilamide and derivatives	SO ₂ NH ₂ or derivative for COOH	Microorganisms
	p-Aminobenzamide	CONH ₂ for COOH	Bacteria
	Carbarsone and related arsenicals	As for C in a COOH group; derivatives of this	Microorganisms, animals
	Phosphonic acid	PO ₃ H ₂ for COOH	Microorganisms
	Heterocyclic acids ¹	N or S for C	Bacteria
	Ring-substituted PAB	Halogen or alkyl for H	Bacteria
	p-Aminoacetophenone and derivatives	COR for COOH	Bacteria
	p-Nitrobenzoic acid	NO ₂ for NH ₂	Bacteria
9 Biotin	Desthiobiotin and derivatives	2 H for S	Microorganisms
	Biotin sulfone	SO ₂ for S	Microorganisms
	Ureylene cyclohexyl aliphatic acids	2 C for S; and derivatives with shorter side chains	Microorganisms
	Desthiobiotin	Loss of S, geometric isomerism	Insects
	Urelenetetrahydrofuryl aliphatic sulfonic acids	O for S, SO ₃ H for COOH	Microorganisms
	Homobiotin	Addition of -CH ₂ -	Microorganisms
10 Choline	Triethyl choline	3 ethyls for 3 methyls	Frog muscle and mice
11 Cocarboxylase	Thiamine-thiazole pyrophosphate	Loss of pyrimidine portion	Carboxylase
12 Cis- or trans- crocetin dimethyl ester	Trans- or cis-crocetin dimethyl ester	Geometric isomerism	Algae
13 Cytidine	Adenosine	OH for H, loss of imidazole ring	Neurospora mutant
14 Desthiobiotin	2-Oxyimidazole aliphatic acids	H for CH ₃	Microorganisms
15 Glutamic acid	Methionine sulfoxide	SOCH ₃ for COOH	Bacteria
	Hydroxyglutamic acid	OH for H	Bacteria
	N-Alkylglutamines	N-Alkyl for OH	Bacteria
16 Guanine	Triazolopyrimidines	N for C	Bacteria
	Benzimidazole	2 C for 2 N	Microorganisms
17 Histamine	Imidazole and derivatives	Elimination or substitution, part of molecule	Smooth muscle, histamine shock in animals
	Diphenhydramine	Opening of ring, O for N, alkylation of N, C	
	Tripeleminamine	Opening of ring, alkylation of N	
18 Hypoxanthine	Hydroxytriazolopyrimidine	N for C	Bacteria
19 Indoleacetic acid	Phenyl butyric acid	Elimination of N and shift of one C	Plants
	Skatyl sulfonic acid	SO ₃ H for COOH	Plants
20 Inositol	Hexachlorocyclohexane	6 Cl for 6 OH	Fungi, plants, pancreatic amylase
21 Isoleucine	Leucine	Position isomerism of one CH ₃	Bacteria
22 Leucine	D-Leucine	Optical inversion	Bacteria
23 Lysine	Arginine	Guanidino for amino, elimination of CH ₂	Neurospora mutant
24 Methionine	Methoxinine	O for S	Bacteria
	Ethionine	CH ₃ for H	Bacteria and animals
	Norleucine	CH ₂ for S	Bacteria
25 Nicotinic acid, (or amide)	Pyridine-3-sulfonic acid or amide	SO ₃ H for COOH	Microorganisms; animals ²
	3-Acetylpyridine	COCH ₃ for COOH	Animals, not in microorganisms
	5-Thiazole carboxamide	S for CH=CH	Certain bacteria
26 Pantothenic acid ³	Thiopicnic acid (pantoyltaurine) and derivatives	SO ₃ H and derivatives for COOH	Microorganisms, pantothenate-utilizing enzymes, not animals
	Pantothenyl alcohol	CH ₂ OH for COOH	Microorganisms, not animals
	α- or β-Methyl pantothenic acid	CH ₃ for H	Microorganisms
	Other substituted panto-amides	Alkyl or OH- and NH ₂ -alkyl for CH ₂ CH ₂ COOH	Microorganisms
	Phenyl pantothenone	COC ₆ H ₅ for COOH	Microorganisms
	Salicyl β-alanine	o-Hydroxy-benzoyl for pantoyl	Microorganisms
	γ ¹ -Methyl pantothenic acid	CH ₃ for H	Bacteria
27 Phenylalanine	β-Hydroxyphenylalanine	OH for H	Bacteria
	Thienylalanine	S for CH=CH	Microorganisms, animals
	Furylalanine	O for CH=CH	Microorganisms
	Halogenated phenylalanines	Halogen for H	Microorganisms
28 Pimelic acid	2, 4-Dichlorosulfanilidocaproic acid	Dichlorosulfanilide for COOH	Biotin indepdt. microorganisms
29 Porphyrins ⁴	Porphyrins lacking vinyl groups		Bacteria
30 Pteroylglutamic acid	Pteroyl-triglutamic acid	Addition of two glutamic acids	Transplanted tumors
	Xanthopterin	Loss of p-amino-benzoyl glutamic acid	Transplanted tumors
31 Pyridoxine	Desoxy pyridoxine	H for OH	Microorganisms, animals
	2-Ethyl-3-amino-4-ethoxymethyl-5-amino-methyl pyridine	CH ₃ for H, NH ₂ for OH, Et for H	Microorganisms
32 Riboflavin	6, 7-Dichlororiboflavin	2 Cl for 2 CH ₃	Microorganisms
	Isoriboflavin	Shift in position of CH ₃	Animals, not bacteria
	Corresponding phenazine	2 C for 2 N, 2 NH ₂ for 2 OH	Microorganisms, animals
	Galactoflavin	Dulcetyl for ribityl	Animals
	Lumiflavin	CH ₃ for ribityl	Bacteria
	Araboflavin	Inversion of position of OH	Animals

/1/ e.g., 6-Aminonicotinic acid. /2/ Alcohol and lactic dehydrogenases, not animals in vivo. /3/ See also table on next page. /4/ e.g., hematin and protoporphyrin.

325. ANTIMETABOLITES (Concluded)

Table adapted from D. W. Woolley's "A Study of Antimetabolites," John Wiley and Sons, 1952.

Part I: SOME METABOLITES AND THEIR ANTAGONISTIC STRUCTURAL ANALOGS (Concluded)

Metabolite	Analog	Structural Alteration	Biological System Affected
33 Succinic acid	Malonic acid	Loss of CH ₂	Succinic oxidase
	Sulfonated succinic acid	SO ₃ H for H	Succinic oxidase
34 Testosterone	Estradiol	Benzene ring for cyclohexane ring, loss of CH ₃	Animals
35 Thiamine	Pyriothiamine	CH=CH for S	Microorganisms, animals
	Oxythiamine	OH for NH ₂	Animals, fish thiaminase
	Butylthiamine	Butyl for CH ₃	Animals
	Aminobenzylmethylthiazolium chloride	2 C for 2 N, loss of side chains	Fish thiaminase
36 Thymine	5-Substituted dioxypyrimidines	NO ₂ or Br or NH ₂ or OH for CH ₃	Bacteria
	2, 4-Diamino- or dithiothymine	NH ₂ or SH for OH	Bacteria
37 α-Tocopherol	α-Tocopherol quinone	Opening of ring by addition of O	Animals
38 Thyroxine	Ethers of diiodotyrosine	p-Nitrobenzyl or p-nitrophenylethyl or benzyl for p-hydroxydiiodophenyl	Tadpoles
39 Tryptophan	Indole acrylic acid	Loss of NH ₃	Bacteria
	Naphthylacrylic acid	Loss of NH ₃ , C=C for N	Bacteria
	Styrylacetic acid	Loss of NH ₂ , substitution of aliphatic unsaturated side chain for pyrrol ring	Bacteria
	Methyltryptophans	CH ₃ for H	Bacteria
	Benzothienylalanine	S for N	Bacteria
	Indole	Loss of side chain	Bacteriophage plus bacteria
40 Tyrosine	3-Fluorotyrosine	F for H	Rats
41 Uracil	Barbituric acid	OH for H	Bacteria
	Thiouracil	S for O	Bacteria, plant seed germination
42 Vitamin K	Dicumarol and derivatives	O for C, side-chain alterations	Animals
	Iodin	2 N for 2 C, side-chain alterations	Bacteria
	α-Tocopherol quinone	2 CH ₃ for benzene ring	Animals
	2, 3-Dichloronaphthoquinone	2 Cl for alkyl side chains	Microorganisms
	2-Substituted-3-hydroxynaphthoquinones	OH for H, change in alkyl substituent	Animals, not bacteria
	Methoxynaphthoquinone	OCH ₃ for CH ₃	Microorganisms

Part II: SOME ANTIMETABOLITES TO PTEROYLGLUTAMIC ACID

Structural Alteration	Organisms Affected	Reversing Effect of Folic Acid
1 x-CH ₃ for H (x = 7 or 9)	Bacteria, chickens, rats, mice, swine, insects	Competitive
2 10-CH ₃ for H	Bacteria	Competitive
3 10-CH ₃ for H, loss of glutamic	Bacteria	Competitive
4 4-NH ₂ for OH	Bacteria, rats, mice, chickens, guinea pigs, insects, humans	Present in some bacteria, poor or absent in animals
5 4-NH ₂ for OH, 10-CH ₃ for H	Bacteria, chickens, rats	Poor or absent in animals
6 4-NH ₂ for OH, 6-phenyl for aminobenzoyl-glutamic, 7-phenyl for H	Bacteria, not animals	Present
7 6-Phenyl for aminobenzoylglutamic, 7-phenyl for H	Chickens, not bacteria	
8 7-OH for H, 9-O for H	Bacteria, rats	Competitive
9 Aspartic for glutamic	Bacteria, rats, mice, chickens	Competitive
10 Quinoxaline for pteridine	Bacteria, not rats	Competitive

Part III: SOME ANTIMETABOLITES TO PANTOTHENIC ACID

Antimetabolite		Structural Alteration	Inhibition Index ¹		
			L. arabinosus	Yeast	L. casei
Alterations of β-Alanine Part					
1	Pantoyltaurine (thiopicnic acid)	SO ₃ H for COOH	1,000	Inhibition not reversible	24,000
2	Pantoyltaurine amide	SO ₂ NH ₂ for COOH			6,400
3	Pantoyltaurine anilides	SO ₂ NHC ₆ H ₅ for COOH			
4	Phenylpantothenone	COC ₆ H ₅ for COOH	4,500		700
5	Tolyl pantothenone	COC ₆ H ₄ CH ₃ for COOH			100
6	Chlorophenyl pantothenone	COC ₆ H ₄ Cl for COOH			230
7	α-Methylpantothenic	CH ₃ for H			1,000
8	β-Methylpantothenic	CH ₃ for H	750		250
9	Pantothenol	CH ₂ OH for COOH	10,000		20,000
10	Methylpantothenol	CH(CH ₃)OH for COOH	50,000		100,000
11	α-Hydroxypantothenic ²	OH for H	2,500		2,500
12	Pantoic hydrazide	NH ₂ for CH ₂ CH ₂ COOH			240
13	Monopantoylalkyldiamines	Alkyl diamine for β-alanine			Approx. 100,000
14	Tolyl sulfone of pantothenic	SO ₂ C ₆ H ₄ CH ₃ for COOH			6,400
15	Anisyl sulfone of pantothenic	SO ₂ C ₆ H ₄ OCH ₃ for COOH			1,600
16	Pantoylpropylamine	CH ₃ for COOH	7,500		10,000
17	Pantoylbutylamine	C ₂ H ₅ for COOH	7,500		15,000
18	Pantoylheptylamine	(CH ₂) ₄ CH ₃ for COOH	4,500		4,250
19	Pantoylphenylethylamine	C ₆ H ₅ for COOH	40,000		10,000
Alterations of Pantoyl Part					
20	γ, γ-Dimethyl-5-hydroxyvaleryl-β-alanine	CH ₂ CH ₂ for CHO	Inhibitory to streptococci but not reversed by pantothenic		
21	γ-Hydroxybutyryl-β-alanine	Loss of methyls and of α-hydroxy			
22	γ'-Methylpantothenic ³	CH ₃ for H	5,000		300
23	Salicylyl-β-alanine	Hydroxybenzoic for pantoic		1,600	12,500
Alterations of Both Portions					
24	β-5-Dihydroxy-γ, γ-dimethylvaleryltaurine	Insertion of CH ₂ , SO ₃ H for COOH	Inhibitory to hemolytic streptococci		

¹/The inhibition index represents the amount of antimetabolite required to overcome the effect of a unit weight of metabolite. The values in this table were calculated from the quantities required to produce maximal inhibition of growth. ²/Complete inhibition of growth could not be achieved with this compound. ³/Nomenclature used for pantothenic acid derivatives is sometimes confusing because some investigators name the α-carbon atom of the entire molecule, whereas others take the α-carbon atom of the pantoyl residue as the α-carbon atom. γ'-Methylpantothenic acid might more correctly be named ω-methylpantothenic acid.

Biological antioxidants, as distinct from antioxidants that protect the unsaturated bonds of such materials as gasoline, rubber, and plastics, are compounds that decrease the rate of fatty peroxidase formation and oxygen uptake at carbon-to-carbon unsaturated bonds of food, feed, or tissue lipids. Compounds listed are only a few of the many occurring in living organisms and having antioxidant activity in vivo or in vitro¹. Some of the antioxidants are known to be toxic to animals, hence inclusion in the table is not to be construed as endorsement for use in foods or diets for animals. Naturally occurring synergistic type antioxidants (e.g., ascorbic acid, citric acid, cephalin, phosphoric acid, certain amino acids) are not included in this table. Synergistic type antioxidants do not impart any appreciable antioxidant activity when used alone with a lipid substrate known to be free of inhibitors or other antioxidants, but when used in combination with one or more primary antioxidants they enhance antioxidant activity.

Antioxidant and Occurrence		Chemical Name and Composition
1	Arbutin. Leaves of the bearberry (<i>Arctostaphylos uva-ursi</i>), a small evergreen shrub, and frequently occurs in plants particularly of the Ericaceae family.	Hydroquinone- β -D-glucoside. $C_{12}H_{15}O_6(OH)$.
Physical and chemical properties		
Long, fine, silky, bitter tasting, colorless needles, MP (water free product) 194-195°C. Almost insol. in ether; slightly sol. in cold water and in alcohol; easily soluble in hot water. Arbutin hydrate (1 mol H_2O) shows $[\alpha]_D^{20} = -60.34^\circ$. Loses water of crystallization at 110-115°C, decomposes on heating to glycosan and hydroquinone. Gives colors with $FeCl_3$, $BiCl_3$, and with HNO_3 . Crystallizes from methyl alcohol as hygroscopic anhydrous crystals which acquire 2 mols H_2O at ordinary conditions. Fehling's solution not reduced, but ammoniacal $AgNO_3$ is, on heating.		
2	Gossypol. In the "gland dots," "secretion cavities" or "resin glands" present in all parts of the cotton plant except the woody tissue.	2,2-bis-1,6,7-Trihydroxy-3-methyl-5-isopropyl-8-aldehydonaphthyl. $C_{30}H_{24}O_2(OH)_6$.
Physical and chemical properties		
Brilliant yellow needles, MP 184°C; other crystal forms with MP of 199°C and 214°C; also a red isomeric crystalline form, MP 184-185°C. Very sol. in cold dioxane, diethylene glycol, methyl-, ethyl-, isopropyl-, and butyl alcohols, ether, ethyl acetate, acetone, chloroform, carbon tetrachloride, and pyridine; slightly sol. in glycerol, cyclohexane, and petroleum ether (BP 60-110°C); and insol. in pet. ether (BP 30-60°C), and in water; sol. in fat, alkali salts; very sol. in water and alcohol. Log molar extinction coefficient: (250 m μ) = 5; (300 m μ) \geq 4; (360 m μ) \leq 4. Alkaline solutions oxidize readily on exposure to air and are extremely sensitive to oxidizing agents. A number of color reactions occur with metallic and other reagents. O-R potential = + 408 mvolts.		
3	Gum Guaiac. From heart wood resin of tropical American trees, <i>Guaiacum officinale</i> Linné and <i>Guaiacum sanctum</i> Linné.	Constituents: α - and β -guaiaconic acids (70.5%), guaiaretic (11%), guaiacinic, guaiacresinic, and guaiacic acids, guaiacsaponin, vanillin, an aromatic oil, a gutta-percha-like substance called guaiaputtin, guaiac yellow. Analysis: 87-96% alc. sol.; 55-75% ether sol.; ash not greater than 3.5%; acid value 46-53; ester value 121-139; sap. value 167-192.
Physical and chemical properties		
Occurs in irregular masses enclosing fragments of plant tissues, or in large, nearly homogeneous masses, occasionally in round or ovoid tears. Externally brownish black to dusky brown, acquiring a greenish color on long exposure; the fractured surface having a glassy luster, the thin pieces being translucent and varying in color from brown to yellowish orange. The powder is moderate yellowish brown, becoming olive brown on exposure to air. Balsamic odor and slightly acid taste. Melting range 85-90°C. Incompletely but readily soluble in alcohol, ether, chloroform, creosote, solutions of alkalis, and in chloral hydrate T.S. Slightly sol. in carbon disulfide and benzene, not readily sol. in fat. An alcoholic solution on addition of $FeCl_3$ tincture or oxidizing agents or enzymes becomes blue changing rapidly to green.		
4	Nordihydroguaiaretic acid. From a desert plant, the creosote bush (<i>Larrea divaricata</i>).	2,3-bis-(3,4-Dihydroxybenzyl)-butane. $C_{18}H_{18}(OH)_4$.
Physical and chemical properties		
White crystalline solid, MP 184-185°C. Slightly sol. in water and dilute acids; moderately sol. in hot benzene and xylene; very sol. in diethyl ether, alcohol, and glacial acetic acid; sol. in fats to the extent of 0.5%.		
5	Sesamol. Believed to occur as the glucoside sesamol in sesame oil.	4-Hydroxy-1,2-methylenedioxy-benzene. $C_7H_5O_2(OH)$.
Physical and chemical properties		
Colorless crystals with a phenolic odor, MP 65.8°C. Easily sol. in alcohol and ether; difficultly sol. in water and petroleum ether; sol. in alkali; sol. in conc. H_2SO_4 with a dark green color. Color reactions with aromatic aldehydes in the presence of HCl; gives a carmoisin red color with furfural in presence of HCl; gives color with ferric iron; azo derivatives colored.		
6	Tannins. Widely distributed in vegetable kingdom. May occur in every part of the seed plant.	All contain polyhydroxy phenols or derivatives, often in complex, condensed ring structures. Hydrolyzable with acids to yield phenolic derivatives and in some instances sugars, usually D-glucose. Alkali fusion and dry distillation give decomposition products principally phenolic in character: catechol, pyrogallol, phloroglucinol, resorcinol, and hydroquinone, or their corresponding acids including pyrocatechuic, pyrogallic, and resorcylic.
Physical and chemical properties		
Generally amorphous, rarely crystalline materials, having an astringent taste. Readily soluble in hot water to form colloidal sols. Precipitated from solution by potassium dichromate, lead acetate, albumin, gelatin, other proteins, and by alkaloids. Give colors (inks) with ferric salts; sols. develop a red color on the addition of potassium ferri-cyanide. When heated with dilute acids, insoluble, amorphous anhydrides or phlobaphenes produced in addition to hydrolysis products. Phlobaphenes are red brown substances practically insoluble in water, chemically relatively inert.		
7	α -Tocopherol (natural or D-form). Non-saponifiable fraction of plant fats and oils; to some extent in land- and marine-animal fats and oils.	5,7,8-Trimethyltolcol, a chroman derivative. $C_{29}H_{49}O(OH)$.
Physical and chemical properties		
Transparent needles, MP 2.5-3.5°C; sol. in fats and fat solv., insol. in water. $E_{1\%}^{1cm}$ (292 m μ) = 71. Infrared maxima at 3.02 μ for hydroxy and 7.85 μ for phenolic C-O linkage; optically active, dextrorotatory in ethyl alc.; compound has 3 centers of asymmetry: carbon 2 of the chroman ring, and 4', 8' of the side chain; 8 isomers possible. Stable to heat, 200°C, when heated alone in absence of oxygen or to heat, 100°C, in presence of HCl or H_2SO_4 . Stable in visible light, unstable in UV light. Acted on by alkali only slowly. Sensitive to oxidation. O-R potential = + 273 mvolts.		
8	β -Tocopherol (natural form). Same occurrence as α -tocopherol.	5,8-Dimethyltolcol. $C_{28}H_{47}O(OH)$.
Physical and chemical properties		
Light yellow or colorless oil. $E_{1\%}^{1cm}$ (297 m μ) = 87.6. O-R potential = + 343 mvolts. Same general properties as those listed for α -tocopherol.		
9	γ -Tocopherol (natural form). Same occurrence as α -tocopherol.	7,8-Dimethyltolcol. $C_{28}H_{47}O(OH)$.
Physical and chemical properties		
Transparent needles, MP -3 to -2°C. $E_{1\%}^{1cm}$ (298 m μ) = 93.2. Infrared maxima at 3.02 μ for hydroxy and 8.17 μ for phenolic C-O linkage. O-R potential = + 348 mvolts. Same general properties as those listed for α -tocopherol.		
10	δ -Tocopherol (natural form). Same occurrence as α -tocopherol.	8-Methyltolcol. $C_{27}H_{45}O(OH)$.
Physical and chemical properties		
Yellow oil. $E_{1\%}^{1cm}$ (298 m μ) = 91.2. Infrared maxima at 3.01 μ for hydroxy and 8.28 μ for phenolic C-O linkage. O-R potential = + 405 mvolts. Same general properties as those listed for α -tocopherol.		

/1/ Some antioxidants not included are butylhydroxyanisole (synthetic), caffeic acid (wide distribution in plants), coffee bean, conidendrin (spruce resin, wood liquor wastes), dihydroquercetin (bark of Douglas fir, Jeffrey pine), diphenyl, p-phenylene-diamine ("DPPD," synthetic), eugenol (clove and nutmeg oils), gallic acid (many tannins), methylene blue (synthetic), pomiferin (fruit of osage orange tree), propyl gallate (synthetic), quercetin (rinds of many fruits, as glycosides of bark and leaves of some plants), vanillin (widely in plants, fruit of *Vanilla planifolia*).

327. DETOXICATION MECHANISMS

Ar = aryl group; Et = ethyl or ethyl group; G = glucuronic acid group; Ph = phenyl group; R = alkyl group; X = any substituted group.

Part I: OXIDATION

The liver is the principal site of action for most of these oxidations.

Substance	Reaction	Products ¹	Remarks
1 Alcohols, primary aliphatic	$RCH_2OH \rightarrow RCHO \rightarrow RCOOH \rightarrow CO_2 + H_2O$	Fatty acids and aldehydes.	Liver principal site of action.
2 Ethyl alcohol	$CH_3CH_2OH \rightarrow CH_3CHO \rightarrow CH_3COOH \rightarrow CO_2 + H_2O$	Acetic acid, acetaldehyde.	Liver principal site of action.
3 2-Ethylhexanol	$C_4H_9CHEtCH_2OH \rightarrow C_4H_9CHEtCOOH \rightarrow C_4H_9CHEtCOOC_6H_5O_6$	2-Ethylhexanoic acid.	Acid forms ester glucuronide.
4 Alcohols, secondary aliphatic	$RR'CHOH \rightarrow RR'CO + RR'CHOC_6H_5O_6$	Ketones.	Partly oxidized, partly conjugated.
5 Isopropyl alcohol	$(CH_3)_2CHOH \rightarrow (CH_3)_2CO$	Acetone.	Mostly oxidized.
6 Higher secondary alcohols	Cf Item 4, above.	Ketones.	Conjugated and/or oxidized.
7 Alcohols, tertiary aliphatic	$RR'R''COH \rightarrow RR'R''COC_6H_5O_6$ (principal reaction)	Difficultly oxidized.	Mostly conjugated.
8 Alcohols, primary aromatic	$ArCH_2OH \rightarrow ArCOOH$	Aromatic acids.	
9 Benzyl alcohol	$C_6H_5CH_2OH \rightarrow C_6H_5COOH$	Benzoic acid.	Hippuric acid excreted.
10 Saligenin	$HO-C_6H_4CH_2OH \rightarrow HOC_6H_4COOH$	Salicylic acid.	Saligenin also directly conjugated.
11 Alcohols, secondary aromatic	$ArCHOHCH_3 \rightarrow ArCOOH + ArCHOHCH_3$	Aromatic acid.	Extensive conjugation as well as oxidation.
12 Methyl phenyl carbinol	$C_6H_5CHOHCH_3 \rightarrow C_6H_5COOH + C_6H_5CHOHCH_3$	Benzoic acid.	Forms glucuronide.
13 Aldehydes, aliphatic	$RCHO \rightarrow RCOOH \rightarrow CO_2 + H_2O$	Fatty acids.	Acid oxidized to CO_2 .
14 Formaldehyde	$HCHO \rightarrow HCOOH \rightarrow CO_2 + H_2O$	Formic acid.	Acid oxidized to CO_2 .
15 Aldehydes, aromatic	$ArCHO \rightarrow ArCOOH$	Aromatic acids.	
16 Benzaldehyde	$C_6H_5CHO \rightarrow C_6H_5COOH$	Benzoic acid.	Hippuric acid excreted.
17 Hydroxyaldehydes	$HOArCHO \rightarrow HOArCOOH + GOArCHO$	Hydroxyaromatic acid.	Some conjugated aldehyde also formed.
18 Ethers, aromatic	$ArOR \rightarrow HOAr'OR$ or $ArOH$	Phenols.	Formed either by oxidation or oxidative demethylation.
19 Methyl phenyl ether (anisole)	$C_6H_5OCH_3 \rightarrow p-HOC_6H_4OCH_3$	p-Methoxyphenol.	Oxidation of aromatic ring.
20 p-Nitroanisole	$p-NO_2C_6H_4OCH_3 \rightarrow p-NO_2C_6H_4OH + HCHO$	p-Nitrophenol.	Oxidative demethylation.
21 Glycols		Corresponding di- and monocarboxylic acids.	Oxidation not thoroughly studied.
22 Ethylene glycol	$(CH_2OH)_2 \rightarrow (COOH)_2$	Oxalic acid.	Glycol not conjugated with glucuronic acid.
23 2, 2-Diethylpropane-1, 3 diol	$Et_2C(CH_2OH)_2 \rightarrow Et_2C(CH_2OH)COOH$	α, α -Diethylhydracrylic acid.	Diol partly conjugated with glucuronic acid.
24 Ketones, aromatic	$ArCOR \rightarrow ArCOOH + ArCHOHR$	Benzoic or phenylacetic acid.	Reduction to carbinols (principal reaction).
25 Acetophenone	$C_6H_5COCH_3 \rightarrow C_6H_5COOH + C_6H_5CHOHCH_3$	Benzoic acid	All acylphenones yield benzoic acid.
26 Benzene	$C_6H_6 \rightarrow C_6H_5OH$ [also o- and p- $C_6H_4(OH)_2$, 1, 2, 4- $C_6H_4(OH)_3$, muonic acid]	Phenol, polyphenols.	Nearly half eliminated unchanged in expired air.
27 Toluene	$C_6H_5CH_3 \rightarrow C_6H_5COOH$	Benzoic acid.	Excreted as hippuric acid.
28 Xylenes	$C_6H_4(CH_3)_2 \rightarrow C_6H_4(CH_3)COOH$	Toluic acids.	Small amts. of xylenols formed.
29 Mono-substituted benzenes (except alkylbenzenes)	$C_6H_5X \rightarrow p-HOC_6H_4X$ (plus o- or p-isomer)	p-Substituted phenols (from all types of substituted benzenes).	Also m-phenols or o-phenols according to type.
30 Aniline	$C_6H_5NH_2 \rightarrow p-HOC_6H_4NH_2 + o-HOC_6H_4NH_2$	p-Aminophenol.	Some o-aminophenol.
31 Nitrobenzene	$C_6H_5NO_2 \rightarrow p-HOC_6H_4NO_2 + m-HOC_6H_4NO_2$	p-Nitrophenol.	Also m-nitrophenol.
32 Polysubstituted benzenes		Phenols.	
33 1, 3, 5-Trichlorobenzene	$1, 3, 5-C_6H_3Cl_3 \rightarrow 1, 2, 4, 6-C_6H_2(OH)Cl_3$	2, 4, 6-Trichlorophenol.	
34 Alkylbenzenes		Secondary carbinols + benzoic or phenylacetic acids.	
35 Ethyl benzene	$PhCH_2CH_3 \rightarrow PhCOOH + PhCHOHCH_3 + PhCH_2COOH$	Benzoic and phenylacetic acids, methyl phenyl carbinol.	
36 Propylbenzene	$PhCH_2CH_2CH_3 \rightarrow PhCOOH + PhCH_2CHOHCH_3 + PhCHOHCH_2CH_3$	Benzoic acid; benzyl methyl and ethyl phenyl carbinols.	Carbinols excreted as glucuronides; acids as glycine conjugates.
37 Isopropylbenzene (cumene)	$PhCH(CH_3)_2 \rightarrow PhCOOH + PhCH(CH_3)CH_2OH + PhCH(CH_3)COOH$	Hydratropic acid, hydratropoyl alcohol, benzoic acid.	
38 tert.-Butylbenzene	$Ph(CH_3)_3 \rightarrow PhC(CH_3)_2CH_2OH$	2, 2-Dimethyl-2-phenylethanol only.	

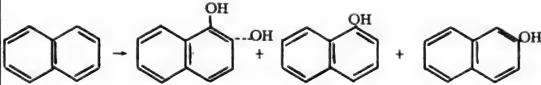
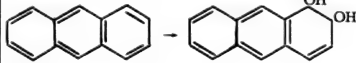
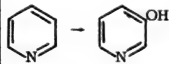
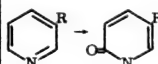
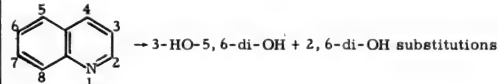
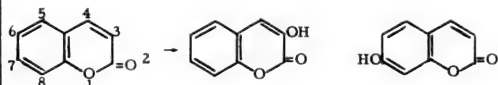
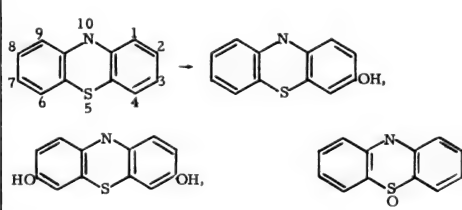
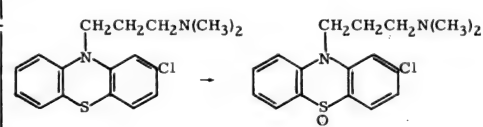
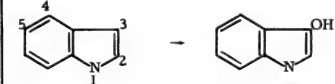
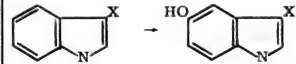
/1/ Other than CO_2 and H_2O .

327. DETOXICATION MECHANISMS (Continued)

Ar = aryl group; Et = ethyl or ethyl group; G = glucuronic acid group; Ph = phenyl group; R = alkyl group; X = any substituted group.

Part I: OXIDATION (Continued)

The liver is the principal site of action for most of these oxidations.

Substance	Reaction	Product ¹	Remarks
39 Alkylbenzenes (concluded) Styrene	$\text{PhCH=CH}_2 \rightarrow \text{PhCOOH}$	Benzoic acid (partly).	Excreted as hippuric acid.
40 Phenylacetylene	$\text{PhC}\equiv\text{CH} \rightarrow \text{PhCH}_2\text{COOH} (+ \text{PhCOOH})$	Phenylacetic and some benzoic acid.	Much eliminated unchanged in breath.
41 Polycyclic hydrocarbons		Phenols and trans-1, 2-dihydro-1, 2-diols.	Free and conjugated.
42 Naphthalene		trans-1, 2-Dihydro-naphthalene-1, 2-diol.	Also 1- and 2-naphthols.
43 Anthracene		1, 2-Dihydro-anthracene-1, 2-diol.	Free and conjugated.
44 Heterocyclic rings		Phenols or hydroxy compounds.	Usually conjugated.
45 Pyridine	 (minor reaction)	3-Pyridinol (trace metabolite).	Major metabolites unknown; N-methylpyridium hydroxide formed in some animals.
46 3-Alkyl pyridines (e.g., nicotinamide)		3-Alkyl -6-ketopyridines.	
47 Quinoline		3-Quinolinol, 5,6- and 2, 6-quinoline-diols.	Conjugated 2-hydroxy-quinoline formed in vitro.
48 Coumarin		3- and 7-Hydroxycoumarins.	Conjugated, 3- is principal phenol.
49 3-Substituted coumarins		7-Hydroxycoumarins.	
50 Phenothiazine		3-Hydroxy-3, 7-dihydroxyphenothiazine, and 5-oxide.	Free and conjugated.
51 Chlorpromazine (10-dimethyl-amino-propyl-2-chloro-phenothiazine)		5-Oxide.	
52 Indole		3-Hydroxyindole (indoxyl).	
53 3-Substituted indoles		5-Hydroxy derivatives.	
54 Phenols		o- and p-Dihydroxy phenols (minor reaction).	Major reaction is conjugation.
55 Phenol	$\text{C}_6\text{H}_5\text{OH} \rightarrow \text{O}-$ and $p-\text{C}_6\text{H}_4(\text{OH})_2$; ($p- > o-$).	Quinol.	Catechol also formed.
56 N-Methylamino compounds, aromatic.	$\text{ArNHCH}_3 \rightarrow \text{ArNH}_2 + \text{HCHO}$.	Aromatic amine + formaldehyde.	Oxidative demethylation.

/1/ Other than CO_2 and H_2O .

327. DETOXICATION MECHANISMS (Continued)

Ar = aryl group; Et = ethyl or ethyl group; G = glucuronic acid group; Ph = phenyl group; R = alkyl group; X = any substituted group.

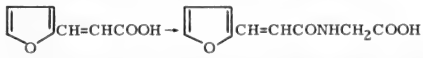
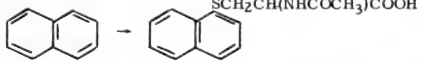
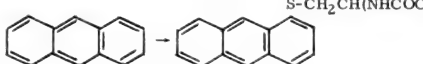
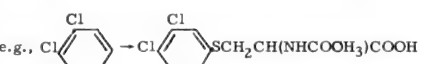

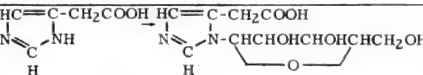
Part II: REDUCTION

Substance	Reaction	Products	Substance	Reaction	Products
1 Ketones, aliphatic and aromatic	$RR'CO \rightarrow RR'CHOH$	Secondary alcohols; also excreted conjugated.	10 Trinitrotoluene (2, 4, 6-)		2, 6-Dinitro-4-aminotoluene.
2 2-Heptanone	$C_5H_{11}COCH_3 \rightarrow C_5H_{11}CHOHCH_3$	2-Heptanol.	11 Azo compounds	$RN=NR' \rightarrow RNH_2 + R'NH_2$	Aromatic amines.
3 Acetophenone	$PhCOCH_3 \rightarrow PhCHOHCH_3$	Methyl phenyl carbinol.	12 Prontosil rubrum		Sulfanilamide, 1, 2, 4-Triamino-benzene.
4 Aldehydes, trisubstituted	$RR'R''CCHO \rightarrow RR'R''CCH_2OH$	Primary alcohols.			
5 Chloral hydrate	$CCl_3CH(OH)_2 \rightarrow CCl_3CH_2OH$	Trichloroethyl alcohol.			
6 p-Quinones (benzo-quinone)		Quinols (quinol).			
7 2-Methyl-1, 4-naphtho-quinone		2-Methyl-1, 4-dihydroxy-naphthalene.	13 Disulfides	$RS-SR' \rightarrow RSH + HSR'$	Sulfhydryl compounds.
8 Nitro compounds, aromatic	$ArNO_2 \rightarrow ArNH_2$	Aromatic amines (partly).	14 Antabuse	$Et_2NCS-S-S-SCNEt_2 \rightarrow Et_2NCSSH$	Diethyldithiocarbamate.
9 Nitrobenzene	$C_6H_5NO_2 \rightarrow p-HOC_6H_4NH_2$	p-Aminophenol.	15 Pentavalent organic arsonic acids	$R-AsO(OH)_2 \rightarrow R-AsO$	Trivalent arsenoxides + minor metabolites(?).
			16 Phenyl-arsonic acids	$C_6H_5AsO(OH)_2 \rightarrow C_6H_5AsO$	Phenylarsenoxide. Reduction a minor reaction.

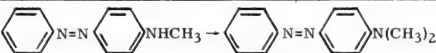
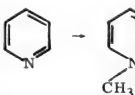
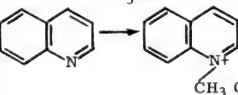
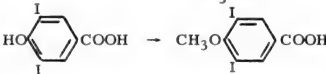
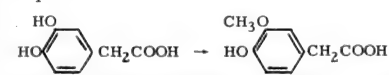
Part III: SYNTHESIS OR CONJUGATION

Substance	Reaction	End Products	Remarks
Acylation			
1 Aliphatic primary amines	$RNH_2 + AcCoA \rightarrow RNHCOCH_3 + CoA$	Acetylaminos.	Uncommon reaction; deamination main reaction.
2 Glucosamine		N-Acetylglucosamine.	
3 Histamine		Acetylhistamine.	Extent of acetylation varies with species.
4 α-Amino acids	$RCH(NH_2)COOH \rightarrow RCH(NHCOCH_3)COOH$	N-Acetyl amino acid.	Occurs in most species with foreign amino-acids and D-isomers. Natural amino acids are reversibly acetylated in intermediary metabolism.
5 γ-Phenyl-α-amino-butyric acid	$Ph-CH_2CH_2CH(NH_2)COOH \rightarrow Ph-CH_2CH_2CH(NHCOCH_3)COOH$	γ-Phenyl-α-acetamidobutyric acid.	
6 S-Phenylcysteine	$Ph-SCH_2CH(NH_2)COOH \rightarrow PhSCH_2CH(NHCOCH_3)COOH$	Phenylmercapturic acid.	
7 Aromatic primary amines	$ArNH_2 \rightarrow ArNHCOCH_3$	Acetylated aromatic amine.	Extent varies with amine; does not occur in dog.
8 Isonicotinic hydrazide	$C_5H_4NCONHNH_2 \rightarrow C_5H_4NCONHNHCOCH_3$	1-Acetyl-2-isonicotinyl hydrazide.	In man, rhesus monkey; not in dog.
9 Sulfanilamide	$p-NH_2C_6H_4SO_2NH_2 \rightarrow p-CH_3CONHC_6H_4SO_2NH_2$	N-Acetyl-sulfanilamide.	In most animals except dog.
Glycine Conjugation			
10 Aromatic acids	$ArCOOH \rightarrow ArCONHCH_2COOH$	Aroylglycines.	
11 Benzoic acid		Hippuric acid.	
12 α- and β-Naphtholic acids		α- and β-Naphthuric acids.	Type: ArCOOH. Also substituted benzoic acids.
13 Nicotinic acid		Nicotinuric acid.	Reaction occurs in mammals, insects, some reptiles, but not in birds.
14 Furoic acid		Furoylglycine (pyromucuric acid).	
15 Thiophene-2-carboxylic acid		Thiphenuric acid.	
16 Substituted acetic acids			Types: ArCH ₂ COOH, ArCHR'COOH, ArCR'R''COOH, and possibly RR'R''CCOOH (some bile acids also form glycine conjugates).
17 Phenylacetic acid	$Ph-CH_2COOH \rightarrow Ph-CH_2CONHCH_2COOH$	Phenaceturic acid.	In mammals except man.
18 Indolylacetic acid		Indolylaceturic acid.	
19 Hydratropic acid	$Ph-CH(CH_3)COOH \rightarrow Ph-CH(CH_3)CONHCH_2COOH$	Hydratropoylglycine.	
20 Phellandric acid		Phellanduric acid.	

327. DETOXICATION MECHANISMS (Continued)
 Ar = aryl group; Et = ethyl or ethyl group; G = glucuronic acid group; Ph = phenyl group; R = alkyl group; X = any substituted group.
 Part III: SYNTHESIS OR CONJUGATION (Continued)

Substance	Reaction	End Products	Remarks
Glycine Conjugation (concluded)			
21 β -Substituted acrylic acids.			Type: $\text{ArCH}=\text{CHCOOH}$; $\text{ArCR}=\text{CHCOOH}$
22 Cinnamic acid	$\text{Ph}-\text{CH}=\text{CHCOOH} \rightarrow \text{Ph}-\text{CH}=\text{CHCONHCH}_2\text{COOH}$	Cinnamoylglycine.	
23 2-Furylacrylic acid		Furfurylacrylic acid.	
24 β -Methylcinnamic acid	$\text{Ph}-\text{C}(\text{CH}_3)=\text{CHCOOH} \rightarrow \text{Ph}-\text{C}(\text{CH}_3)=\text{CHCONHCH}_2\text{COOH}$	β -Methylcinnamoylglycine.	
Glutamine Conjugation			
25 Phenylacetic acid	$\text{Ph}-\text{CH}_2\text{COOH} \rightarrow \text{Ph}-\text{CH}_2\text{CONHCH}(\text{COOH})\text{CH}_2\text{CH}_2\text{CONH}_2$	Phenylacetylglutamine.	Occurs in only man and chimpanzee.
Ornithine Conjugation			
26 Aromatic acids		N, N'-Diaroyl-ornithines (or ornithuric acids). Ornithuric acid.	Occurs only in birds and some reptiles.
27 Benzoic acid (also substituted benzoic acids)	$\text{Ph}-\text{COOH} \rightarrow \text{Ph}-\text{CONHCH}_2\text{CH}_2\text{CH}_2\text{CH}(\text{COOH})\text{NHCOC}_6\text{H}_5$		
28 Furoic acid		Difuroylornithine.	} Hens.
29 Nicotinic acid		Dinicotinylornithine.	
30 Phenylacetic acid		Diphenacetylornithine.	
Cysteine Conjugation			
31 Aromatic hydrocarbons	$\text{ArH} \rightarrow \text{ArSCH}_2\text{CH}(\text{NHCOC}_6\text{H}_5)\text{COOH}$	N-Acetyl-S-aryl-cysteines or mercapturic acids.	Not all polycyclic hydrocarbons form mercapturic acids.
32 Benzene	$\text{C}_6\text{H}_6 \rightarrow \text{Ph}-\text{SCH}_2\text{CH}(\text{NHCOC}_6\text{H}_5)\text{COOH}$	Phenylmercapturic acid.	
33 Naphthalene		1-Naphthylmercapturic acid.	
34 Anthracene		1-Anthrylmercapturic acid.	
35 Halogenated aromatic hydrocarbons		Mercapturic acids.	Tetra- and penta-chlorobenzenes form little if any mercapturic acid.
36 Bromobenzene	$\text{Ph}-\text{Br} \rightarrow p\text{-BrC}_6\text{H}_4\text{SCH}_2\text{CH}(\text{NHCOC}_6\text{H}_5)\text{COOH}$	p-Bromophenylmercapturic acid.	In large amounts.
37 o- and m-Dichlorobenzene	e.g., 	Dichlorophenylmercapturic acid.	p-Dichlorobenzene is not conjugated.
38 Benzyl chloride	$\text{Ph}-\text{CH}_2\text{Cl} \rightarrow \text{Ph}-\text{CH}_2\text{SCH}_2\text{CH}(\text{NHCOC}_6\text{H}_5)\text{COOH}$	Benzylmercapturic acid.	
39 Some chloronitrobenzenes		Mercapturic acids.	Conjugation occurs by replacement of chloro- or nitro-groups.
40 Pentachloronitrobenzene	$\text{C}_6\text{Cl}_5\text{NO}_2 \rightarrow \text{C}_6\text{Cl}_5\text{SCH}_2\text{CH}(\text{NHCOC}_6\text{H}_5)\text{COOH}$	Pentachlorophenylmercapturic acid.	Acetylcysteinyl denitration.
41 2,4-Dichloronitrobenzene		5-Chloro-2-nitrophenylmercapturic acid.	Acetylcysteinyl dechlorination.
Glycoside Conjugation			
42 Primary alcohols	$\text{RCH}_2\text{OH} \rightarrow \text{RCH}_2\text{OG}$	Alkylglucuronides, RCH_2OG .	Minor metabolites; oxidation principal reaction.
43 Ethanol	$\text{CH}_3\text{CH}_2\text{OH} \rightarrow \text{CH}_3\text{CH}_2\text{OC}_6\text{H}_4\text{O}_6$	Ethyl glucuronide.	Minor metabolite.
44 2,2-Dimethyl-2-phenylethanol	$\text{Ph}-\text{C}(\text{CH}_3)_2\text{CH}_2\text{OH} \rightarrow \text{Ph}-\text{C}(\text{CH}_3)_2\text{CH}_2\text{OG}$	2,2-Dimethyl-2-phenylethylglucuronide.	Major metabolite.
45 Secondary alcohols	$\text{RR}'\text{CHOH} \rightarrow \text{RR}'\text{CHOG}$	Alkylglucuronides, $\text{RR}'\text{CHOG}$.	} Principally conjugation.
46 Pentan-2-ol	$\text{C}_3\text{H}_7\text{CHOHCH}_3 \rightarrow \text{C}_3\text{H}_7\text{CHOGCH}_3$	2-Pentylglucuronide.	
47 Tertiary alcohols	$\text{RR}'\text{R}''\text{COH} \rightarrow \text{RR}'\text{R}''\text{COG}$	Alkylglucuronides, $\text{RR}'\text{R}''\text{COG}$.	
48 tert.-Butanol	$(\text{CH}_3)_3\text{COH} \rightarrow (\text{CH}_3)_3\text{COG}$	tert.-Butylglucuronide.	
49 Phenols (all types)	$\text{ArOH} \rightarrow \text{ArOG}$	Arylglucuronides, ArOG .	} Occurs with α -substituted fatty acids.
50 Phenol		Phenylglucuronide.	
51 Aliphatic acids		Acylglucuronides, RCOOG .	
52 Diethylacetic acid	$(\text{C}_2\text{H}_5)_2\text{CHCOOH} \rightarrow (\text{C}_2\text{H}_5)_2\text{CHCOOG}$	Diethylacetylglucuronide.	
53 Aromatic amines	$\text{ArNH}_2 \rightarrow \text{ArNHG}$	N-Glucuronides.	Probable.
54 Phenol	$\text{Ph}-\text{OH} \rightarrow \text{Ph}-\text{OC}_6\text{H}_{11}\text{O}_5(\beta-)$	β -Phenylglucoside.	Occurs in insects, not in mammals.
55 Imidazoleacetic acid	$\text{HC}=\text{C}-\text{CH}_2\text{COOH} \rightarrow \text{HC}=\text{C}-\text{CH}_2\text{COOH}$ 	1-(3)-Ribosylimidazole-4-(5)-acetic acid.	Occurs in rats and mice.

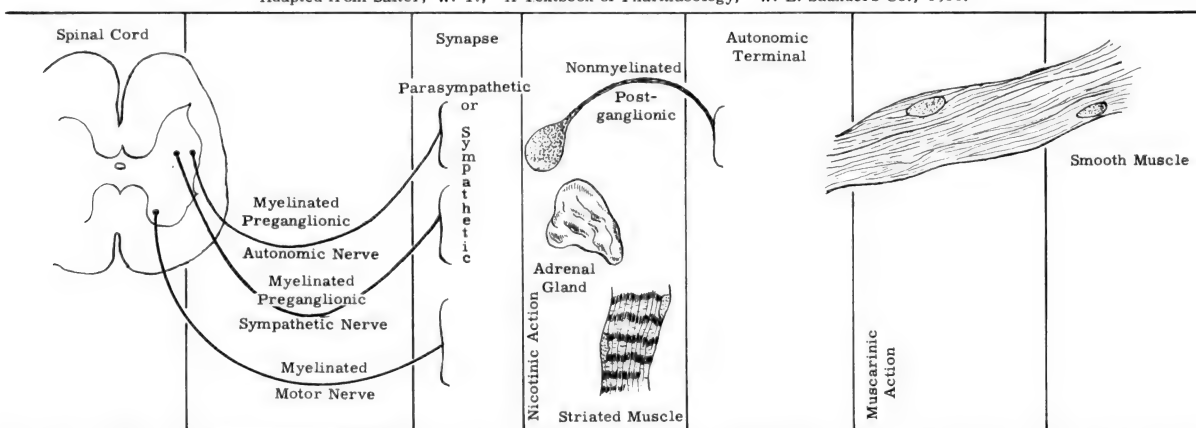
327. DETOXICATION MECHANISMS (Concluded)
 Ar = aryl group; Et = ethyl group; G = glucuronic acid group; Ph = phenyl group; R = alkyl group; X = any substituted group.
 Part III: SYNTHESIS OR CONJUGATION (Concluded)

Substance	Reaction	End Products	Remarks
Ethereal Sulfate Formation			
56 Phenols	$\text{Ph-OH} \rightarrow \text{PhOSO}_3\text{H}$	Arylsulfuric acids.	Occurs with phenols of pK_a 6-11.
57 Aromatic amines	$\text{ArNH}_2 \rightarrow \text{ArNHSO}_3\text{H}$	Sulfamates.	Probable.
Thiocyanate Formation			
58 Cyanide ions	$\text{CN}^- \rightarrow \text{CNS}^-$	Thiocyanate.	Specific for CN^- .
Methylation			
59 Monomethylaminoazobenzene		Dimethylaminoazobenzene.	Extremely rare.
60 Heterocyclic tertiary nitrogen			
61 Pyridine		N-Methylpyridinium hydroxide.	Occurs in many species, but only to a slight extent in rabbits.
62 Quinoline		N-Methylquinolinium hydroxide.	Occurs in dog, swine, goat, hen, frog, to slight extent in rabbit, not in rat.
63 3,5-Diiodo-4-hydroxybenzoic acid		3,5-Diiodo-4-methoxybenzoic acid.	In man only.
64 3,4-Dihydroxyphenyl acetic acid		4-Hydroxy-3-methoxyphenyl acetic acid.	In man and rabbit.

328. DRUGS AFFECTING THE AUTONOMIC NERVOUS SYSTEM

Part I: SITE OF ACTION

Adapted from Salter, W. T., "A Textbook of Pharmacology," W. B. Saunders Co., 1953.



Structure						
1	Preganglionic Cell Body	Preganglionic Fiber	Preganglionic Fiber Terminal To Ganglion Cell	Ganglion Cell and Postganglionic Fiber	Postganglionic Fiber Terminal to Receptor Substance	Receptor Substance
1			Acetylcholine	Mediator	Acetylcholine or sympathin.	Effector Substance
Stimulant Drugs						
2	Apomorphine.		Eserine, DFP, HETP, TEPP.	Acting on ganglia: Nicotine (trace), acetylcholine, mecholyl.	Parasympathetic: Neostigmine, eserine, DFP, HETP, TEPP.	Muscarine, arecoline, pilocarpine, acetylcholine, methacholine, carbamoylcholine (eserine).
3					Sympathetic: Ephedrine	Epinephrine, arterenol, ephedrine, amphetamine.
Inhibitory or Blocking Drugs						
4				TEAC, C ₅ , C ₆ , nicotine (excess), sympathomimetics, (banthine, atropine), acetylcholine (excess).	Parasympathetic: Atropine, hyoscine, banthine.	(Atropine).
5					Sympathetic: Dibenamine, ergot, benzodioxane, yohimbine.	(Ergot), benzodioxane.

328. DRUGS AFFECTING THE AUTONOMIC NERVOUS SYSTEM (Continued)

The use of trade names in this table is for informative purposes only and in no way implies endorsement by The National Academy of Sciences -- The National Research Council.

Part II: CHEMISTRY AND TOXICOLOGY

TD = toxic dose; PO = oral; SC = subcutaneous; IP = intraperitoneal; IM = intramuscular; IV = intravenous.

TD = Toxic dose; PO = Oral; SC = Subcutaneous; IP = Intraperitoneal; IM = Intramuscular; IV = Intravenous.									
Common or Trade Name, Synonyms	Chemical Name	Structure	Pressor Activity (Epinephrine Equivalent)	Toxicity mg/kg					
				Animal (Dose)	PO	SC	IP	IM	IV
Sympathomimetic Drugs									
1 Amphetamine, (Benzedrine)	dl- α -Methylphenethylamine		1:100-1:300	Mouse (LD ₅₀) Rabbit (LD ₅₀) Rat (LD ₅₀)	42 11 39-165	75 30	10	10	
2 Phenylpropylmethylamine, (Vonedrine)	dl-N, β -Dimethylphenethylamine		1:600	Mouse (LD ₅₀) Rabbit (LD ₅₀) Rat (LD ₅₀)	540 205 850	165	220	72	
3 d-Desoxyephedrine HCl, (Pervitin)	d-N, α -Dimethylphenethylamine hydrochloride		1:100-1:300	Mouse (LD ₅₀) Rat (MLD)	75 17				
4 Mephentermine	N, α -Trimethylphenethylamine sulfate								
5 Mydratine, (dl-Nor-ephedrine HCl)	α -(1-Aminoethyl) benzyl alcohol hydrochloride		1:60-1:300	Mouse (LD ₅₀) Rabbit (LD ₅₀) Rat (LD ₅₀)	600 255 380-860	300 160	320	50	
6 l-Ephedrine	l-Phenyl-2-methylamino-propanol		1:100-1:300	Mouse (LD ₅₀) Rabbit (LD ₅₀) Rat (LD ₅₀)	600 165 320-550	325 165	175	60	
7 l-N-Ethylephedrine HCl, (Nethamine HCl)	2-Methylethylamino-1-phenyl-1-propanol hydrochloride		Hypotensor						
8 Hydroxyamphetamine, (Paredrine)	dl-p-Hydroxy- α -methylphenethylamine		1:50-1:100	Guinea pig (LD ₅₀) Mouse (LD ₅₀)	180	430			
9 p-(2-Methylamino-propyl)-phenol, (Veritol)	p-Hydroxy-N, α -dimethylphenethylamine		1:30-1:250	Rat (LD ₅₀)		100			
10 Synephrin tartrate, (Sympatol)	p-Hydroxyphenolmethylaminoethanol tartrate		1:116	Mouse (MLD) Rabbit (MLD)	700-800		65	50	
11 Phenylephrine HCl, (Neo-Synephrine HCl)	l-m-Hydroxy- α -(methylaminomethyl) benzyl alcohol		1:56	Mouse (LD ₅₀) Rabbit (LD ₅₀) Rat (LD ₅₀)	22 22 27-33	330	7.2	0.5	
12 Methoxyphenamine HCl, (Orthoxine HCl)	β -(o-Methoxyphenyl) isopropylmethylamine hydrochloride		1:1000	Rat (LD ₅₀)			60		
13 Epinine HCl	3,4-Dihydroxyphenyl-ethylmethylamine hydrochloride		1:10-1:12						
14 l-Arterenol, (l-Nor-epinephrine; l-Noradrenaline)	l- α -(Aminomethyl)-3,4-		1:2-1:5	Mouse (LD ₅₀) Rat (LD ₅₀)			5; 0.10 ¹ 0.10; 1.40 ¹		
15 3,4-Dihydroxynorephedrine HCl, (Cobefrine HCl)	3,4-Dihydroxyphenylpropanolamine hydrochloride		1:4-1:12	Rabbit (MLD) Rat (LD ₅₀)			11 8		
16 Butanefrine HCl	α -(1-Aminopropyl) protocatechuyl alcohol hydrochloride		Hypotensor	Mouse (LD ₅₀)			117		
17 Epinephrine, (Adrenaline)	3,4-Dihydroxy- α -(methylaminomethyl) benzyl alcohol		1:1	Mouse (LD ₅₀) Rat (LD ₅₀)		13 ²	2.7 ² ; 50 ³ 0.04 ² ; 0.80 ³		
18 N-Methylepinephrine, (N-Methyladrenaline; Methadren)	α -(Dimethylaminomethyl) protocatechuyl alcohol		1:10-1:25	Mouse Rabbit	250		40		
19 Isopropylarterenol, (Isuprel)	α -(Isopropylaminomethyl) protocatechuyl alcohol		Hypotensor	Mouse (LD ₅₀)		450	83		
20 Methoxamine HCl, (Vasoxyl HCl)	2-Amino-1-(2,5-dimethoxyphenyl)-1-propanol hydrochloride			Mouse (LD ₅₀)	92				
21 Naphazoline HCl, (Privine HCl)	2-(1-Naphthylmethyl) imidazoline hydrochloride			Mouse (LD ₅₀) Rabbit (LD ₅₀) Rat (LD ₅₀)	170 0.95 325-385	50	0.95	0.8	
22 N-1-Dimethylhexylamine, (Oenethyl)	2-Methylaminoheptane								
23 Tuaminoheptane, (Tuamine)	1-Methylhexylamine		1:320	Mouse (LD ₅₀) Rabbit (LD ₅₀) Rat (LD ₅₀)	115 130 135-169	75 34	85	22	
24 Octin	6-Methylamino-2-methylheptene			Dog (LD) Mouse (LD ₅₀) Rabbit (LD ₅₀)	76.3 171 101			25.8 17.5 17.6	
25 N, α -Dimethylcyclohexaneethylamine, (Benzedrex)	N-Methyl- β -cyclohexylisopropylamine		1:333-1:500	Guinea pig (LD ₅₀) Rabbit (LD ₅₀) Rat (LD ₅₀)		85 80-90 65-75			
26 Cyclopentamine HCl, (Clopane HCl)	N, α -Dimethylcyclopentaneethylamine hydrochloride								

/1/Second value for d-arterenol. /2/ l-epinephrine. /3/ d-epinephrine.

328. DRUGS AFFECTING THE AUTONOMIC NERVOUS SYSTEM (Continued)

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Part II: CHEMISTRY AND TOXICOLOGY (Continued)

TD = toxic dose; PO = oral; SC = subcutaneous; IP = intraperitoneal; IM = intramuscular; IV = intravenous.

Common Name		Structure		Adrenolytic Action			Toxicity	
				Rabbit Uterus	Guinea Pig Seminal Vesicle	Epinephrine Hypertensive Reversal, Dog mg/kg, IV	Species (Route)	LD ₅₀ ⁴ mg/kg
				Isolated (Ergotamine=1)				
For lines 27-31: lysergic acid, [R], d-proline, and [R'] are joined in amide linkages.								
27 Ergocornine	1-Valine		Dimethylpyruvic acid	0.5	2		Rabbit (IV)	1.17
28 Ergocristine	1-Phenylalanine		Dimethylpyruvic acid	1.0	4		Rabbit (IV)	2.17
29 Ergocryptine	1-Leucine		Dimethylpyruvic acid	1.5	4		Rabbit (IV)	1.05
30 Ergotoxine	1-Phenylalanine		Dimethylpyruvic acid					
31 Ergotamine	1-Phenylalanine		Pyruvic acid					
32 Ergonovine	Lysergic acid-NH-CH(CH ₃)OH			1	1	0.2-0.5	Mouse (IV) Rabbit (IV) Rat (IV)	62 3.55 80
33 Dihydroergotamine ⁵	5,10-dihydro derivative of ergotamine			2.25	7	0.2-0.5	Mouse (IV) Rabbit (IV) Rat (IV)	118 25 110
34 Dihydroergocornine	5,10-dihydro derivative of ergocornine		- methane sulfonate	2.5	25		Rabbit (IV)	35
35 Dihydroergocristine	5,10-dihydro derivative of ergocristine		"Hydergine"	3.5	35		Rabbit (IV)	27
36 Dihydroergocryptine	5,10-dihydro derivative of ergocryptine			5.0	35		Rabbit (IV)	19
37 Yohimbine (Quebrachine; Coryn- nine; Aphrodine)	Chemical Name (Chief alkaloid of Cry- nanthe johimbe; 10 iso- mers known)	Structure 		1:200		1	Guinea pig (IP) Mouse (PO) Mouse (IV)	42 (TD) (86.7-1000) (TD) 16 (TD)
38 N-(2-Chloroethyl)- dibenzylamine HCl (Dibenamine HCl)	β-Chloroethylidibenzyl- amine hydrochloride					10-20	Cat (IV) Mouse (SC) Mouse (IP) Mouse (IV)	35 400-500 75-100 50
39 Benzazoline HCl, (Priscoline HCl)	z-Benzyl-4,5-imidazoline hydrochloride					10		
40 Piperoxan HCl, (933F)	2-(1-Piperidylmethyl)-1, 4-benzodioxan hydro- chloride			1:100			Mouse (IP)	180 (TD)
41 Prosympal, (883F)	2-(Diethylaminoethyl)- benzodioxan			1:200		1	Frog (SC) Guinea pig (SC) Mouse (SC) Rabbit (SC) Rabbit (IV)	250 (TD) 400 (TD) 500 (TD) 300 (TD) 30 (TD)
42 Regitine, (C7337)	2-(N'-p-tolyl-N'-m- hydroxyphenylamino- ethyl) imidazoline						Mouse (PO) Rabbit (PO) Rat (PO)	750 2000 1250

/4/ Unless otherwise indicated in parentheses. /5/ D. H. E. 45.

328. DRUGS AFFECTING THE AUTONOMIC NERVOUS SYSTEM (Continued)

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Part II; CHEMISTRY AND TOXICOLOGY (Continued)

TD = toxic dose; PO = oral; SC = subcutaneous; IP = intraperitoneal; IM = intramuscular; IV = intravenous.

Parasympathomimetic Drugs								
Common or Trade Name, Synonyms	Chemical Name	Structure	Pressor Activity	Toxicity, mg/kg				
				Species (Dose)	PO	SC	IP	IM	IV
43 Acetylcholine, (Pragmoline; Acecoline)	(2-Hydroxyethyl)-trimethylammonium Bromide or Chloride		1	Mouse (TD) Rabbit (TD) Rat (TD)	3000 2500 250	170 250		20 0.15
44 Methacholine, (Mecholyl)	Acetyl-β-methylcholine bromide or chloride		1	Mouse (TD)	1100			
45 Carbachol, (Choline chloride carbamate; carbamoylcholine chloride)	(2-Hydroxyethyl) tri-methylammonium chloride carbamate		5-10 (Dog); 1 (Rabbit)	Dog (TD) Guinea pig (TD) Mouse (TD)	25	0.1 0.075 0.5		0.5
46 Vasodilatateur 2249F, (Dilvasene)	(1, 3-Dioxolan-4-ylmethyl) trimethylammonium iodide		0.5-0.2	Guinea pig (TD) Mouse (TD) Rat (TD)	300	5 35 25		2.5
47 Furfurethonium Iodide, (Furmethide Iodide)	Furfuryltrimethylammonium iodide			Rat (LD ₅₀)		90		
48 Muscarine	Alkaloid of Amanita muscaria			Cat (TD)		2-4		
49 Pilocarpine	Alkaloid of Pilocarpus jaborandi							
50 Arecoline	Methyl-1, 2, 5, 6-tetrahydro-1-methylnicotinate			Mouse (TD)		65		
51 Physostigmine ⁶ , (Eserine)	Main alkaloid of Calabar bean (Physostigma venenosum)			Cat (LD ₅₀) Mouse (LD ₅₀) Rabbit (LD ₅₀)	3	0.75 3		0.68 0.45 0.5-0.8
52 Neostigmine Bromide ⁶ , (Prostigmine Bromide)	(m-Hydroxyphenyl) tri-methylammonium bromide or methylsulfate dimethylcarbamate			Mouse (LD ₅₀) Rabbit (LD ₅₀)	12-16 1	0.5-0.75		0.30 0.25
53 Benzpyrinium Bromide ⁶ , (Stigmonene Bromide)	1-Benzyl-3-(dimethyl-carbamoyloxy) pyridinium bromide							
54 DFP ⁶	Diisopropyl fluorophos-phate			Cat (LD ₅₀) Dog (LD ₅₀) Mouse (LD ₅₀) Rabbit (LD ₅₀) Rat (LD ₅₀)	36.8 3.71 9.78			1.63 3.43 0.34

Parasympatholytic Drugs

Common or Trade Name, Synonyms	Chemical Name	Structure	Toxicity, mg/kg				
			Species (Dose)	PO	SC	IP	IM IV
55 Atropine, (dl-Hyoscyamine)	dl-Tropyltropate		Cat (TD) Dog (TD) Guinea pig (TD) Mouse (TD) Mouse (LD50) Rabbit (TD) Rat (TD) Rat (LD50)		125-150 175-200 300-400 794 1400-1500 200-500 700-750	215	50-100 70 68-90.8 41
56 Scopolamine, (Hyoscine)							
57 Genatropine	Atropine-N-oxide		Dog (TD)				200

/6/ Inhibitor of cholinesterase.

328. DRUGS AFFECTING THE AUTONOMIC NERVOUS SYSTEM (Continued)

The use of trade names in this table is for informative purposes only and in no way implies endorsement by The National Academy of Sciences -- The National Research Council.

Part II: CHEMISTRY AND TOXICOLOGY (Concluded)

TD = toxic dose; PO = oral; SC = subcutaneous; IP = intraperitoneal; IM = intramuscular; IV = intravenous.

Common or Trade Name, Synonyms	Chemical Name	Structure	Species (Dose)	Toxicity, mg/Hg					
				PO	SC	IP	IM	IV	
58 Homatropine, (Mydrasine)	Mandelyltropine (methylbromide)		Guinea pig (LD ₅₀) Mouse (LD ₅₀) Rat (LD ₅₀)	1000 1400 1200	650 800	120 60 82			
59 Amprotropine Phosphate, (Syntropan)	3-Diethylamino-2, 2-dimethylpropyltropate phosphate		Mouse (LD)		1600			70	
60 Eucatropine HCl	4-Hydroxy-1, 2, 2, 6-tetramethylpiperidine mandelate hydrochloride								
61 Trasentine	2-Diethylaminoethyl α-phenyl cyclohexanecetate HCl		Mouse (LD ₅₀) Rat (LD ₅₀)	780		220 250		27 32	
62 Trocinate	β-Diethylaminoethyl diphenylthioacetate hydrochloride								
63 Propivane, (117RP)	2-Diethylaminoethyl propylphenylacetate hydrochloride								
64 Artane Trihexylphenidyl	α-Cyclohexyl-α-phenyl-1-piperidinepropanol hydrochloride		Mouse (LD ₅₀) Rat (LD ₅₀)			162 195		39 30	
65 Pavatrine HCl	2-Diethylaminoethyl 9-fluoreneboxylate hydrochloride		Mouse (LD)			320			
66 Cyverine HCl	Methyl-bis (β-cyclohexylethyl) amine hydrochloride								
67 Dibutoline Sulfate, (Dibuline Sulfate)	Bis [(dibutylcarbamate) of ethyl (2-hydroxyethyl) dimethylammonium] sulfate		Rat (LD ₅₀)			22			
68 Dicyclomine HCl, (Bentyl)	1-Cyclohexylhexahydrobenzoic acid, β-diethylaminoethyl ester hydrochloride								
Curariform Drugs									
69 Diethazine Base, or HCl, (Diparcol Base or HCl; 2987RP)	10-(2-Diethylaminoethyl) phenothiazine		Mouse (LD ₅₀) Rabbit (LD ₅₀)		450 200			45 25	
70 Caramiphen HCl, (Parpanit)	1-Phenylcyclopentane-carboxylic acid 2-diethylaminoethyl ester hydrochloride		Cat (LD ₅₀) Mouse (LD ₅₀) Rabbit (LD ₅₀) Rat (LD ₅₀)	390		222.3 209		45.1 24.5	
71 Gallamine Triethiodide, (Flaxedil; 3697RP; 2559F)	[v-Phenyltris (oxyethylene)]-tris [triethylammonium iodide]		Dog (LD ₅₀) Mouse (LD ₅₀) Rabbit (LD ₅₀) Rat (LD ₅₀)	425 100	15 25		2.3	0.8 4.5 24.5 5.5	
72 Myanesin	3-o-Toloxyl-1, 2-propanediol		Mouse (LD ₅₀)			560			
Ganglion-Blocking Drugs									
73 T.E.A. Chloride, (Etamon); TEAB	Tetraethylammonium bromide or chloride		Dog (LD ₅₀) Mouse (LD ₅₀) Rat (LD ₅₀)	900 2630		65	58 110	36.4 56.3	
74 Hexamethonium Bromide (Hexameton)	Hexamethylenebis [trimethylammonium bromide]								

328. DRUGS AFFECTING THE AUTONOMIC NERVOUS SYSTEM (Continued)

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Part III: CLINICAL APPLICATIONS
Numbers in brackets refer to drugs listed in Part II.

Drug Number	Principal Uses	Possible Side Effects or Severe Reactions	Contraindications	Route of Administration ¹
Sympathomimetic Drugs				
1 [1]	CNS stimulant in narcolepsy, certain depressive conditions, post-encephalitic parkinsonism.	May produce overstimulation, restlessness, insomnia, G.I. upset, chills; collapse and syncope may follow overdosage. Preliminary small test dosages obviate hypertensive reactions or cardiovascular disease.	Anxiety, hyperexcitability or restlessness	PO.
2 [2]	Nasal decongestant.			TOP.
3 [3]	CNS stimulant.	Euphoria, tachycardia, hypertension. Hypersensitivity may cause headache, irritability, vertigo, insomnia and collapse.	Hypertension, heart diseases, or thyrotoxicosis.	PO.
4 [4]	In severe hypotensive states; cardiac and general surgery, spinal anesthesia.		Peripheral vascular collapse.	IV, IM.
5 [5]	Bronchial dilation; nasal vasoconstriction.	Hypertension, tachycardia, and nervous excitation.	Severe hypertension or cardiac disease, thyrotoxicosis.	PO, TOP.
6 [6]	In asthma and allergic disorders; to increase blood pressure; locally, to shrink mucosa of nose; treatment of syncope due to complete heart block.	Nervous insomnia, tachycardia and cardiac consciousness, sweating, headache, hypertension, anxiety.	Thyrotoxicosis, heart disease, hypertension.	PO, IM, SC, TOP.
7 [7]	In bronchial asthma, allergic manifestations; vasomotor rhinitis.	Insomnia; nausea.	Diabetes, severe cardiovascular diseases, marked hyperthyroidism.	PO.
8 [8]	Vasoconstrictor; in postural hypotension, carotid sinus syndrome, nasal decongestion.	Nervous system stimulation, hypertension.	Severe hypertension, cardiac disease, or glaucoma.	PO, TOP.
9 [9]	In hypotension; for pupil dilatation.	Nervous system stimulation, hypertension.	Severe hypertension, cardiac disease.	PO.
10 [10]	Hypertensive in mild collapse caused by failing peripheral blood flow.		Cardiac disease, diabetes, or thyroid disorders.	PO, TOP.
11 [11]	In paroxysmal tachycardia, shock, and shock-like states.	Tingling or coloring of skin; "fullness" of the head; transient precordial pain; hyperthyroidism; certain cardiac conditions; hypertension in the aged.		
12 [12]	In bronchial asthma, acute urticaria, G.I. allergy.	Mild nervous excitation; nausea; hypotension; slight drop in systolic blood pressure, more pronounced in those with hypertension.	Advanced cardiac disease or hypotension.	PO.
13 [13]	Nasal vasoconstrictor.	Tachycardia, hypertension, nervous excitation.	Thyrotoxicosis.	TOP.
14 [14]	In acute hypotensive states, trauma, central vasomotor depression, hemorrhage.	Hypertensive and arteriosclerotic disease.	Use of cyclopropane anesthesia or myocardial ischemia.	IV.
15 [15]	Vasoconstrictor, particularly with local anesthetic.	Comparable to epinephrine (see [17]).		
16 [16]	In bronchial asthmatic paroxysms.		Hypersensitivity to "sympathomimetic amines."	IV, SC.
17 [17]	In asthma, hay fever, acute allergic states, shock; vasoconstrictor applied topically or with local anesthetic.	Anxiety, palpitation, vertigo, headache; acute elevation of blood pressure and vasomotor collapse may occur.	Thyrotoxicosis, cardiac disease, or cerebral arteriosclerosis; cyclopropane or ether anesthesia.	IM, SC, TOP.
18 [18]	Hyperglycemic with local anesthetic.	Hypertension, nervous excitation.	Severe hypertension, cardiac disease.	
19 [19]	Vasoconstrictor; in asthma, allergic states.	Acute hypertension, nervous excitation, palpitations, tachycardia.	Thyrotoxicosis, severe cardiac disease.	SL, IH.
20 [20]	In hypotension, post-operative collapse.			IM.
21 [21]	Nasal vasoconstrictor. As effective as epinephrine but more prolonged action.	Overdose may cause drowsiness, tachycardia, hypertension.	Thyrotoxicosis, severe hypertension, cardiac disease.	TOP.
22 [22]	In hypotension produced by spinal anesthesia.	Hypertension, nervous excitation, headache, dizziness, tachycardia, palpitations.	Thyrotoxicosis, cardiac disease.	IV, IM.
23 [23]	In rhinitis and allergic conditions.			TOP, IH.
24 [24]	Antispasmodic, in vesical and ureteral spasms.	Dizziness, headache.	G.I. obstruction.	PO, IV, SC.
25 [25]	Shrink nasal mucosa. Lacks centrally stimulating properties of amphetamine.			IH.
26 [26]	Nasal decongestant.	Overdose may cause rise in blood pressure, nervousness, occasional nausea, dizziness.		TOP, IH.
Sympatholytic Drugs				
27 [27, 28, 29]	Peripheral vascular disorders; hypotensive agent.	Hypertension, collapse, colic, nausea, vomiting.	Pregnancy, serious cardiac disease.	SC, SL.
28 [30]	Oxytocic.	Hypertension, tachycardia, vomiting.	Pregnancy, early stages of labor; peripheral vascular disease; diseases of liver, kidneys.	
29 [31]	Oxytocic; in migraine.	Chronic reactions: gangrene of digits; mental confusion.	Pregnancy, serious cardiac disease.	
30 [32]	Oxytocic; in migraine.	G. I. disturbances, hypertension, tachycardia, tremor, excitement, convulsions, exophthalmus (?).		

/1/ PO = orally; IV = intravenous; IM = intramuscular; SC = subcutaneous; TOP = topically; SL = sublingually; IH = inhalation; ION = iontophoresis; MI = miotic; REC = rectally.

328. DRUGS AFFECTING THE AUTONOMIC NERVOUS SYSTEM (Continued)

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Part III: CLINICAL APPLICATIONS (Continued)
Numbers in brackets refer to drugs listed in Part II.

Drug Number	Principal Uses	Possible Side Effects or Severe Reactions	Contraindications	Route of Administration ¹
31 [33]	In migraine.	Nausea, vomiting, weakness, cardiac irregularity.	Pregnancy; peripheral vascular disease; diseases of the liver, kidneys.	IV, IM, SC.
32 [34, 35, 36]	Clinically used for adrenergic blocking and peripheral vasodilatation in peripheral vascular diseases.		Hypotension.	IM.
33 [37]	Formerly: aphrodesiac, local anesthetic, mydriatic.	Hypotension, kidney injury.	Renal disease.	
34 [38]	In Raynaud's disease, erythromelalgia, causalgia, hypertension, pheochromocytoma.	Usually: postural hypotension; occasionally: nausea, diarrhea, mental confusion.	Arteriosclerosis.	
35 [39]	Vasodilator; in peripheral disease.	Possible peptic ulcer or gastritis; may cause transient syncope.		IV, IM, SC.
36 [40]	Diagnostic agent: detection of epinephrine-producing tumors.	Tachycardia, palpitation, flushing; cold, clammy extremities; hypernoia, nervousness, mild headache, fright, dizziness.		IV.
37 [41]	Sympatholytic vasodilator; analgesic; angors.	Cardiac, digestive disturbances; sedation; bronchitis.		PO.
38 [42]	Diagnostic agent; pheochromocytoma. In vascular disease, hypertensive emergencies.			PO, IV, IM.
Parasympathomimetic Drugs				
39 [43]	In peripheral vascular diseases, attacks of paroxysmal tachycardia, hypertension, intestinal or bladder atony (post-operative), spasmic occlusion of retinal artery.	Flushing, sweating, vertigo, marked salivation, nausea, vomiting.		IV, IM, SC.
40 [44]	In auricular paroxysmal tachycardia, chronic ulcers, Raynaud's disease, low peripheral blood circulation.	Hypotension; cardiac slowing or arrest.	Allergy, asthma, hyperthyroidism; recent coronary occlusion or severe illness. Never administered IV or IM.	PO, SC, ION.
41 [45]	In urinary retention, post-operative abdominal distension, peripheral vascular diseases (vasospasm), threatened gangrene. Veterinary uses.	Flushing, abdominal pain, vomituration, headache, asthmatic attacks. Counteraction by atropine.	Asthma or allergic patients suspected of latent asthma. Never administered IV or IM.	PO, SC, TOP, (MI).
42 [46]	Vasodilator; in hypotension, peripheral vascular (Raynaud's) disease.	Flushing, sweating, salivation. Counteraction by atropine.	Never administered IV.	PO, TOP (MI).
43 [47]	In bladder atony, glaucoma.	Cystitis.	Mechanical obstruction of bladder. Never administered IV.	PO, SC.
44 [48]	Experimental pharmacology.	Salivation; lacrimation; vomiting; profuse diarrhea; cardiac slowing; collapse; may progress to convulsions, coma and death in few hours.		
45 [49]	Miotic; in glaucoma, atropine poisoning. Formerly: to increase sweating.	Sweating, salivation, cardiac irregularities, pulmonary edema, increased G.I. motility.	Asthma; pulmonary, cardiac disease.	TOP(MI), SC.
46 [50]	Miotic; in glaucoma.	Cardiac slowing, salivation and miosis.		TOP(MI).
47 [51]	Miotic; in glaucoma; in stimulation of G.I. or bladder activity; myasthenia gravis distension or atony of intestines.	Salivation, lacrimation, tremor and depression of cardiorespiratory system.	Asthma.	IM, SC, TOP.
48 [52]	In glaucoma, atony of G.I. tract and bladder, myasthenia gravis, muscular spasms in poliomyelitis.	Salivation, lacrimation, nervous excitation and depression of cardiorespiratory system.	Asthma or mechanical obstruction of intestines.	PO, IM, SC.
49 [53]	In atony of G.I. tract and bladder, myasthenia gravis, migraine, tachycardia, muscular spasms in poliomyelitis.	Asthma.	Asthma or mechanical obstruction of intestines.	PO, IM.
50 [54]	In glaucoma.	Blurred vision, pain in eyes and brow, ciliary spasm and pericorneal injection. Orally: nausea, vomiting and diarrhea. Systemic administration: prolonged salivation, lacrimation, intestinal cramps, shock, collapse.	Never administered systemically.	TOP.
Parasympatholytic Drugs				
51 [55 ²]	Symptomatic treatment of post-encephalitic parkinsonism and paralysis agitans; cardio- and pyloro-spasm; mydriasis and cycloplegia; suppression of excessive salivation; syncope resulting from carotid sinus hypersensitivity or cardiac block.	Dryness of mouth, blurred vision, persistent cycloplegia, tachycardia, excitement and dermatitis.	Glaucoma, corneal ulcer.	PO, IM, SC, TOP.
52 [56]	Hypnotic and sedative. Locally: as substitute for atropine in ophthalmology.	Thirst, dryness of mouth, dilatation of pupil, tachycardia, delirium, ataxia and muscular weakness.	Glaucoma.	PO, SC, TOP.
53 [57]	G.I. disturbances.	Similar to but less toxic than atropine sulfate. Cf 51 [55].		
54 [58 ³]	Mydriatic, cycloplegic.	Similar to but less toxic than atropine sulfate. Cf 51 [55].	Glaucoma	TOP.

/1/ PO = orally; IV = intravenous; IM = intramuscular; SC = subcutaneous; TOP = topically; SL = sublingually; IH = inhalation; ION = iontophoresis; MI = miotic; REC = rectally. /2/ As atropine sulfate. /3/ As homatropine hydrobromide.

328. DRUGS AFFECTING THE AUTONOMIC NERVOUS SYSTEM (Concluded)

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Part III: CLINICAL APPLICATIONS (Concluded) Numbers in brackets refer to drugs listed in Part II.

Drug Number	Principal Uses	Possible Side Effects or Severe Reactions	Contraindications	Route of Administration ¹
55 [59]	Antispasmodic, for smooth muscle; in encephalitic parkinsonism.	Overdosage: may cause convulsions.		PO, IM, SC.
56 [60]	Mydriatic.		Glaucoma.	TOP.
57 [61]	Antispasmodic.	Tachycardia, restlessness and nervous excitation.	Glaucoma.	PO, IM, REC.
58 [62]	Antispasmodic, for smooth muscle.	All the advantages of atropine sulfate, none of the disadvantages. Cf 51 [55].		PO.
59 [63]	Antispasmodic, for G. I. and urogenital disorders.	Ten times less toxic than atropine sulfate. Cf 51 [55].		PO, SC, REC.
60 [64]	Parkinsonism.	Blurring of vision, nausea, dryness of mouth, dizziness, "fullness" in head, agitation, confusion.	Glaucoma.	PO.
61 [65]	Antispasmodic.	Tachycardia, nervous excitability.	Glaucoma.	PO.
62 [66]	In pylorospasm, colitis.	Tachycardia, restlessness and nervous excitability.	Glaucoma.	
63 [67]	In G.I., urogenital, biliary spasm; mydriatic; cycloplegic.	Dryness of mouth, mydriasis, moderate hypotension.	Glaucoma.	TOP.
64 [68]	Antispasmodic, for smooth muscle.	Therapeutic dosages: virtually without pupillary, secretory, and cardiac effects of atropine sulfate. Cf 51 [55].		PO.
Curariform Drugs				
65 [70]	In parkinsonism, muscular spasm, tremor.			
66 [71]	For muscular relaxation.	Neostigmine bromide (Cf 52 [56]) should be available.		
67 [72]	Depression of reflex excitability in such conditions as hemiplegia, paraplegia.	Paralysis.	Myasthenia gravis.	
Ganglion-blocking Drugs				
68 [73]	Bromide: diagnostic and therapeutic in peripheral vascular affections; diagnostic in hypertension. Chloride: peripheral vascular disorders and arteriosclerosis; diagnostic in hypertension.	Bromide: hypotension. Chloride: reduction of blood pressure, disturbance of accommodation.	Bromide: severe cerebral or cardiac vascular occlusive disorders. Chloride: severe coronary heart disease or cerebral vascular arterial disease.	IV, IM.
69 [74]	ANS blocking agent.			

/1/ PO = orally; IV = intravenous; IM = intramuscular; SC = subcutaneous; TOP = topically; SL = sublingually; IH = inhalation; ION = iontophoresis; MI = miotic; REC = rectally.

329. EQUIVALENT ANESTHETIC EFFECTS OF GASES: INTACT ANIMALS AND ISOLATED EXCITABLE TISSUES

Gas	ED ₅₀ ¹	Blockade ²	Concentration of Gas in Non-aqueous Phase ³	Gas	ED ₅₀ ¹	Blockade ²	Concentration of Gas in Non-aqueous Phase ³
		atm	(x 10 ⁻⁴ mole fraction)			atm	(x 10 ⁻⁴ mole fraction)
1 Helium	163		125	6 Krypton	1.8		47
2 Nitrogen	18		80	7 Xenon	0.51	12	49
3 Argon	12.6	340	111	8 Nitrous oxide	0.58	13	66
4 Methane	2.9	110	60	9 Ethylene	0.47	12	58
5 Sulfur hexafluoride	1.87	None	41	10 Cyclopropane	0.045	1.9	

/1/ The partial pressure required to abolish the M.E.C. response to electroshock, in 50% of a large group of mice. /2/ The partial pressure required to abolish reversibly the impulse transmission in isolated rat sciatic nerve. /3/ ED₅₀ times mole fraction in benzene at 1 atmosphere.

330. ANESTHESIA, STAGES AND PLANES: MAN

Designation	Characteristics	General Signs	Drug
1 Stage I (Analgesia)	Senses benumbed; consciousness retained.	Appearance and feeling of well-being. Sense of pain diminished.	All drugs that will produce surgical anesthesia, stage III.
2 Stage II (Delirium)	Consciousness lost; respiration irregular; movement of skeletal muscles probable.	Eyeballs move from side to side, or strabismus may be present.	All drugs that will produce surgical anesthesia, stage III.
3 Stage III (Surgical anesthesia)			
Plane 1	Swallowing reflex abolished; muscle relaxation is minimal; respiration regular and even.	Eyeballs moving, or strabismus is present. Pupils are of pre-anesthetic size. Eyelid reflex is abolished.	Ethylene, nitrous oxide.
Plane 2	Muscle relaxation increased. Intercoastal musculature still active in respiration (inspiration). Movements of diaphragm are of normal range. Respirations are regular and even.	Eyeballs are fixed in mid-line.	Chloroform, cyclopropane, di-vinyl ether, ether, ethyl chloride, morphine, pentothal, trichlorethylene.
Plane 3	Muscle relaxation further increased and suitable for intra-abdominal surgery. Inspirations are quickened and shortened. Expirations and the inter-respiratory pause are more prolonged.	Eyeballs are fixed in mid-line. Pupils are slightly larger than pre-anesthetic. The light reflex is present but sluggish.	All drugs as in plane 2.
Plane 4	Skeletal muscle relaxation is complete. Bronchial (cough) reflexes are dulled. Respiration becomes gasping, and is maintained entirely by the diaphragm. The expiratory phase is further prolonged. Cyanosis may be present. Blood and pulse pressure fall, while pulse rate increases.	Pupils are widely dilated and do not react to light. Conjunctivae are glassy.	Same as plane 2.
7 Stage IV (Overdose or respiratory paralysis)	Cessation of respiration. Extreme relaxation of skeletal musculature. Death in few minutes if respiration not restored.	Eyes fixed in mid-line. Pupils dilated and not reactive to light.	

331. DRUGS AFFECTING THE NEUROMUSCULAR JUNCTION

The use of trade names is for informative purposes only and should not be interpreted as endorsement by the National Academy of Sciences - National Research Council. Values for blocking potency are approximations. For further details on other effects of these drugs, consult appropriate tables.

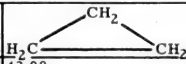
Drug	Animal ¹	Neuromuscular Blocking Potency mg(cation)/kg	LD ₅₀ mg(cation)/kg	Antagonist or Antidote	Other Effects
Decamethylene-1, 10-bis-trimethylammonium dihalide (Decamethonium halide; C ₁₀ ; Eulissin; Syncurine)	Man	0.02-0.025		Hexa- or pentamethonium.	Cardiovascular.
	Cat	0.015-0.018		Hexa- or pentamethonium, stilbazolinium salts.	
	Monkey	0.125		Hexa- or pentamethonium.	
	Mouse	0.35	0.4-0.5		
	Rabbit	0.04-0.09		Hexa- or pentamethonium.	Anticholinesterase; muscarinic.
	Rat	1.25	1.5		
	Chick	0.025			
	Frog ²	5.5-6.2	>123	Hexa- or pentamethonium.	Contracture.
Dihydro-β-erythroidine (C ₁₆ H ₂₁ NO ₃)	Man	0.7-1.4			Hypotensive; bradycardia.
	Cat ³		1.8-2.7		
	Dog				Bradycardia.
	Mouse ³		8.4	Neostigmine.	
	Rabbit ³		9-18		
	Rat ³		207		
Triethiodide of 1, 2, 3-tri(diethylaminoethoxy)benzene (Flaxedil; Gallamine triethiodide) C ₆ H ₃ [O-CH ₂ -CH ₂ -N(C ₂ H ₅) ₃] ₃ · 3I	Frog ²	0.45			
	Man	0.45-0.6		Neostigmine, tensilon.	Histamine release; parasympathetic.
	Cat	0.3-1.1			
	Dog	0.25	0.5	Tensilon.	
	Mouse	1.2	1.9-2.7		
	Rabbit	0.2-0.3	0.4	Neostigmine.	
Decamethylene bis-[1-(3',4'-dimethoxybenzyl)-6,7-dimethoxy-2-methyl-1,2,3,4-tetrahydroisoquinolinium]dimethosulfate (Laudolissin) C ₅₄ H ₈₀ N ₂ O ₁₆ S ₂	Rat		3.3		Histamine release.
	Frog ²	6 and 36			
	Man	0.1		Neostigmine.	Histamine release.
	Cat	0.1			Ganglion blocking.
	Mouse	0.2	0.35		
	Rabbit	0.02	0.04	Neostigmine.	
2,5-bis-(3-Diethylaminopropylamino)-benzoquinone-bis-benzyl chloride (Mytolon chloride; Win 2747; Benzoquinonium chloride) C ₃₄ H ₅₀ N ₄ O ₂ Cl ₂	Rat	1.05	1.8		
	Chick	0.25			
	Man	0.06-0.24			Bradycardia, salivation bronchorrhea.
	Cat ⁴	9.5	11.7		
	Dog	0.1		Neostigmine.	
	Mouse ³	0.5	1.4(0.5 i.v.)		
bis-(Trimethylammonium-ethyl)succinate dihalide; Dimethohalide of bis-2-Dimethylaminoethyl succinate (Suxamethonium halide; Succinylcholine; Succinylcholine; Scoline; Brevedil M; Celocurine; Anectine; Lysthenon; Curacit) CH ₂ -CO-O-CH ₂ -CH ₂ -N(CH ₃) ₃ · 2 halide	Rabbit	0.025	0.04	Neostigmine.	
	Rat		1.1		
	Man	0.1-0.3		Plasmacholinesterase.	Anticholinesterase; nicotinic; initial stimulation of muscular contraction.
	Cat	0.05-0.1			Nicotinic; initial stimulation of muscular contraction.
	Dog	0.1	0.15	Plasmacholinesterase.	Anticholinesterase.
	Mouse	0.05-0.1	0.25		
bis-(Dimethylethylammonium-ethyl)succinate dihalide, or Diethohalide of bis-2-dimethylaminoethyl succinate (Suxethonium halide; Brevedil E; Tachycurine; 362.I.S.; M115; M and B 2210) CH ₂ -CO-O-CH ₂ -CH ₂ -N(CH ₃) ₂ C ₂ H ₅ · 2 halide	Rabbit	0.1	0.5		
	Sparrow	5.0	10.0		Contracture.
	Frog ²	2.5			Nicotinic; contracture.
	Man	0.5-13			
	Dog	0.08-0.25	0.17	Plasmacholinesterase.	Anticholinesterase.
	Rabbit	0.45	0.84		
Toxiferine I chloride (C-Toxiferine I chloride) C ₂₀ H ₂₃ N ₂ OCl · 3 H ₂ O	Frog ²	14.0			
	Man				Histamine release.
	Cat	0.003-0.018	0.018	Neostigmine.	Ganglion blocking; salivation.
	Dog	0.005			
	Mouse	0.005-0.009	0.01		
	Rabbit	0.004-0.01	0.007		
d-Tubocurarine chloride (Tubarine) C ₃₈ H ₄₄ N ₂ O ₆ Cl ₂ · 5 H ₂ O	Frog ²	0.005-0.013			
	Man	0.08-0.19		Neostigmine, tensilon.	Cardiovascular; histamine release.
	Cat	0.12-0.23			Histamine release; ganglion blocking.
	Dog	0.08-0.15	0.38	Tensilon.	Ganglion blocking.
	Monkey	0.06			
	Mouse	0.06-0.09	0.11-0.15		
	Rabbit	0.09-0.15	0.165	Neostigmine.	Ganglion blocking.
	Rat	0.04-0.06	0.08		Histamine release.
d-O, O-Dimethyltubocurarine iodide (Dimethyl ether of d-tubocurarine iodide; Dimethine; Metubine) C ₄₀ H ₄₈ N ₂ O ₆ I ₂ · 3 H ₂ O	Chick	0.13			
	Frog ²	1.4, 4.1 and 7.5	>20.0	Acetylcholine.	
	Man	0.027		Tensilon, neostigmine.	
	Cat	0.02			Ganglion blocking; histamine release.
	Mouse	0.08-0.1	0.16		
	Rabbit	0.01-0.015	0.02	Neostigmine.	
	Rat	0.009	0.025-0.03	Neostigmine.	Histamine release.
	Frog ²	0.94	14.4		

/1/ Unless otherwise indicated, drug administered by intravenous injection. /2/ Ventral lymph sac injection. /3/ Subcutaneous injection.

/4/ Oral administration.

332. GASEOUS AND VOLATILE AGENTS USED IN ANESTHESIA:

Data presented in this table are substantiated by experimental and clinical evidence. Except in a few instances, and so indicated, unauthenticated

Characteristic	Gaseous Agents		
	Nitrous Oxide	Ethylene	Cyclopropane
Physical and Chemical Characteristics			
1 Chemical formula	N_2O	$H_2C=CH_2$	
2 Molecular weight	44.02	28.05	42.08
3 Color, odor, taste	Colorless, odorless, tasteless or sweet.	Colorless, slightly sweet.	Colorless, odor like petroleum benzene, pungent.
4 Specific gravity ⁴	1.53	0.97	1.45
5 Boiling point, °C	-89	-103.9	-37
6 Range of flammability in ⁵ :			
Air	Not flammable, but supports combustion.	3.05-28.6%.	2.45-10.45%.
Oxygen		3.10-79.9%.	2.48-60.00%.
8 Stability to alkali ⁶	Stable.	Stable.	Stable.
9 Oil Ratio ⁷	0.437	1.599	6.99
Blood	0.412=1.06	0.123=13	0.457=15.3
10 Potency ⁸ , %	25	30	100
11 Methods of administration ⁹	Semi-closed, closed.	Semi-closed, closed.	Closed.
12 Induction time ¹⁰ , average	Less than 5 min without hypoxia.	2-3 min without hypoxia.	2-5 min.
13 Recovery time ¹¹ , average	Rapid, 2-3 min.	Rapid, 2 min.	Immediate to 15 min.
14 Concentration in inspired air for ¹² :			
Analgesia, %	20-40	25-35	4-6
Surgery, %	85-90	80-85	13-25
16 Respiratory arrest, %	Not without anoxia.	Not without anoxia.	40
17 Blood concentration for ¹² :			
Surgery	23.3 vol %.	11.2-12.6 vol %.	4.5-9.1 vol %; 16-20 mg %.
18 Respiratory arrest	Not without anoxia.	Not without anoxia.	39 vol %; 30 mg %.
19 Routes of elimination ¹³	Lungs, small quantity through skin.	Lungs, small quantity through skin.	Lungs, small quantity through skin.
Physiological Effects ¹⁴			
20 Respiratory center	Not affected. ¹⁵	Not affected.	Decreased response to carbon dioxide; decreased minute volume.
21 Carotid body	Not affected. ¹⁵	Not affected. ¹⁵	Not affected. ¹⁵
22 Larynx	Reflex not abolished; no spasm without hypoxia.	Reflex not abolished; no spasm without hypoxia.	Frequent laryngospasm.
23 Cilia	None without hypoxia.	Initial stimulation.	
24 Bronchi	Minimal bronchoconstriction or not affected.	Not affected.	Tends to produce bronchoconstriction.
25 Carotid sinus	Increased sensitivity or not affected.	Little effect.	Little effect.
26 Heart	None without hypoxia.	None without hypoxia.	Bradycardia, A-V nodal rhythm, ventricular extrasystoles, ventricular tachycardia, ventricular fibrillation, reduction in cardiac reserve.

/1/ Marketed as Vinethene which has added to it 3.5% alcohol to decrease its rate of vaporization, and 0.01% phenyl-a-naphthylamine as a preservative an improvement over diethyl ether. /3/ Stabilized with 0.01% thymol and tinted (for anesthetic use) to distinguish it from chloroform which has /5/ Range of inflammability for all inflammable agents lies within the anesthetic range. Non-inflammable agents either support combustion or produce and calcium hydroxide, is used to absorb CO_2 in all closed systems. /7/ A loose term, sometimes refers to water or blood, or to vegetation is a partial function of the oil:blood ratio. /8/ A relative term indicating the ability of an anesthetic agent to take a patient from consciousness to the central nervous system. There is a progressive brain depression from cortex to lower centers, followed by an ascending paralysis of the administration of a volatile anesthetic by dropping the agent on a gauze-covered wire-mesh face mask. "Semi-open" is the same technique, with the rebreathes the same mixture of gas with suitable means for the absorption of carbon dioxide and the introduction of a continuous supply of oxygen and tion" is the blowing of the anesthetic vapor and oxygen into the pharynx or trachea in sufficient quantity and rate to maintain anesthesia. /10/ Average individual metabolism, rate and depth of ventilation, cardiovascular system, effect of previously administered drugs, addiction to barbiturates or ation and average depth of anesthesia--particularly the depth at termination of surgery--effective ventilation, status of the cardiovascular system, oxide. /12/ Concentrations to produce a given plane of anesthesia vary considerably from individual to individual. Each patient must be carefully end products, probably related to the metabolism of chloroform and trichlorethylene, have been discovered in the urine. /14/ Those listed presup-autonomic blocking agents, sympathicomimetic agents, endocrines, and muscle relaxants, significantly modify these effects. /15/ No data available among anesthesiologists.

CHEMICAL, PHYSICAL, AND PHYSIOLOGICAL CHARACTERISTICS

impressions and opinions have not been included. Blank spaces indicate unavailability of data.

Volatile Agents					
Diethyl Ether	Divinyl Oxide ¹	n-Propyl Methyl Ether ²	Chloroform	Trichlorethylene ³	Ethyl Chloride
Physical and Chemical Characteristics					
C ₂ H ₅ -O-C ₂ H ₅	CH ₂ =CH-O-CH=CH ₂	C ₃ H ₇ -O-CH ₃	CHCl ₃	HC1C=CCl ₂	CH ₃ CH ₂ Cl
74.12	70.09	74.08	119.39	131.40	64.52
Colorless, pungent, irritating, sweetish, burning.	Colorless, odor like garlic.	Colorless, ethereal, unpleasant, non-irritating.	Colorless, ethereal, burning, sweet.	Colorless, similar to chloroform.	Colorless, ethereal, burning.
0.713-0.716	0.767-0.771	0.726	1.474-1.478	1.456-1.462	0.921
2.56	2.2		4.12	4.53	2.23
35	28-31	39	61	86-88	12-13
1.85-25.9%	1.70-27.0%	Same as diethyl ether.	Not flammable, but produces phosgene near naked flames.	Not flammable in air, but products of decomposition explosive.	4.0-14.8%
2.1-82.0%	1.8-85.0%			10.3-64.5%	4.05-67.2%
Stable.	Stable.		Little decomposition under anesthetic conditions; some carbon monoxide produced.	Decomposes, producing dichloroethylene and phosgene.	Hydrolysed slowly by alkali.
4.1	41.3	10±1	147.5-275.0 1.42-2.77	34.4	15.3
100	100	100	100	25-30	100
Open; semi-open; closed; semi-closed; insufflation, rectally.	Open; semi-open; closed; semi-closed.	Open; semi-open; closed; semi-closed; insufflation.	Open; semi-open; closed(?); semi-closed; insufflation.	Semi-closed; rectally.	Open; semi-open; closed.
10-15 min.	15 sec-5 min; average one min.	5 min.	5 min.	Difficult induction 5-10 min.	15 sec-5 min; average one min.
$\frac{1}{2}$ -2 hr.	Rapid, almost immediate on discontinuing agent.	Prolonged up to 3 hr.	$\frac{1}{4}$ -1 hr.	2-5 min.	Rapid, almost immediate.
	Almost impossible to produce.			0.5	2-3
6.1-13.7 vol %.	3.9 10-12		0.67	5.0-7.5	3.6-4.5 6
120 mg %.	11-18 mg %.	40-70 mg %.	9.2 mg %.		20-30 mg %.
154 mg %.	68 mg %.		>16.5 mg %.		40 mg %.
87% by lungs; remainder in urine, perspiration and by exposed serous surfaces.	Lungs, small amount in urine.	Probably same as diethyl ether.	98% by lungs; some in urine possibly as trichlormethyl-glucuronate.	Lungs, urine.	Exclusively through lungs.
Physiological Effects ¹⁴					
Decreased response to carbon dioxide; increased minute volume.	Stimulated in minimal dosage.	Irregular, fairly quiet respirations.	Depressed.	Tachypnea and shallow irregular breathing in deep planes; sudden respiratory arrest.	Depressed.
Markedly depressed.			Remains active ¹⁵ .		
Laryngospasm caused by direct irritant effect.	Laryngospasm infrequently.		Laryngospasm caused by high concentrations.	Minimal tendency to laryngospasm.	Infrequent laryngospasm.
Possibly initial stimulation, later decrease in activity.			Decreased activity.		
Bronchodilatation.	Bronchodilatation.		Bronchodilatation.		
Markedly depressed in deep planes.	Stimulated in light planes; depressed in deep planes.		Stimulated to 1%; but depressed by higher concentrations.		
Auricular extrasystoles, A-V nodal tachycardia; in deep planes dilatation and decreased force of contraction.	A-V nodal tachycardia or no notable cardiac effect.	No change in electrocardiogram.	Ventricular extrasystoles, nodal and ventricular rhythms, ventricular tachycardia; incidence increased by adrenalin, overdosage, and anoxemia.	Nodal rhythm, ventricular extrasystoles, pulsus bigeminus.	Increase in cardiac irritability during induction; myocardial depression; slight decrease in cardiac output.

ative. /2/ Included here as an example of a recent product developed in the search for an ideal anesthetic agent, although it has not proved itself to be a similar odor. /4/ Water and air are the reference points and in each case equal unity. Upper figures of the volatile agents are the liquid phase. duce toxic products in the presence of a flame. /6/ A mixture of sodium hydroxide and calcium hydroxide, or of barium hydroxide, and the rate of desaturation to death without hypoxia, according to the accepted stages and planes (see Table 330). Anesthetic agents produce a depression of all tissues, particularly the respiratory and cardiovascular centers function until death is produced by an agent of 100% potency. /9/ "Open" means addition of an occlusive material wrapped about the face mask to increase the concentration of the vapor. "Closed" is the method in which the patient is rebreathed. "Semi-closed" is the same technique except that expiration partly escapes into the atmosphere via an exhalation valve. "Insufflation" induction time depends on several factors including the following: chemical or physiological properties and concentration of the anesthetic, narcotic, and experience of the anesthetist. /11/ Average recovery time is related to many factors including, fat solubility of the anesthetic, duration of anesthesia (such as the aspiration of pus, blood, or vomitus), bouts of severe hypoxia, and persistent accumulation of carbon dioxide equilibrated with the anesthetic. /13/ It is assumed that many anesthetic agents are excreted, principally by way of the lungs, unchanged. However, administration of a single agent with adequate oxygen and without accumulation of carbon dioxide. Other drugs, such as metabolic depressants, are able in the literature or available data sketchy and based on clinical impression or animal experiments. Statements are from consensus of opinion

332. GASEOUS AND VOLATILE AGENTS USED IN ANESTHESIA:

Data presented in this table are substantiated by experimental and clinical evidence. Except in a few instances, and so indicated, unauthenticated

Characteristic	Gaseous Agents		
	Nitrous Oxide	Ethylene	Cyclopropane
Physiological Effects ¹⁴ (concluded)			
27 Eyeball activity	Present, becomes fixed in prolonged anesthesia.	Present at all times.	Fixed in 2nd to 3rd plane.
28 Pupillary size ¹⁶	Dilated, becomes constricted in prolonged anesthesia.	No effect.	Constricted, becomes dilated in 3rd plane
29 Salivary glands	None without hypoxia.	None without hypoxia.	90% increase in secretion during induction.
30 Liver	Retention of bromsulphthalein for few post-operative days.	None without hypoxia.	Bromsulphthalein may be retained from 15-30% post-operatively, bile secretion increased.
31 Kidney	None without hypoxia.	None without hypoxia.	31% decrease glomerular filtration, 52% decrease renal plasma flow, 35% increase filtration fraction; slight decrease urine flow; increased tubular reabsorption.
32 Spleen	Not affected. ¹⁵	Not affected. ¹⁵	Dilated. ¹⁵
33 Adrenals	No secretion without hypoxia.	No secretion without hypoxia. ¹⁵	Some secretion of adrenalin (cats).
34 Stomach and intestines	Slight increase in peristalsis followed by decreased tone in recovery period.	Decreased gastric secretion and gastric emptying time; little effect, in deeper planes inhibition of peristalsis.	Little effect; in deeper planes inhibition of peristalsis; some increase in tone; some spasm of colonic muscles.
35 Uterus	Contractions essentially unaltered.	Slight decrease in strength of contractions.	Decreased strength of contractions.
36 Skeletal muscles	Inadequate relaxation.	Moderate relaxation.	Adequate muscle relaxation obtainable.
37 Blood volume ¹⁷	Increased because of increase in red cell mass.	No significant change. ¹⁵	Increased because of increase in red cell mass.
38 Body temperature	Not affected. ¹⁵	Slight fall caused by muscular relaxation.	Skin temperature tends to rise.
39 Peripheral blood vessels	Vasodilatation.	Vasodilatation.	Vasodilatation; in capillaries rapid restricted flow and increased vasomotion.
40 Autonomic effect	None.	Not sympathicomimetic, not parasympathicomimetic.	Parasympathicomimetic, late adrenolytic effect(?).
41 Metabolic rate	Decreased.	Decreased.	Decreased.
42 Acid base balance	None without anoxia.	None without anoxia.	Respiratory acidosis occurs; clinically unimportant tendency for fixed acids to rise.
43 Special features	Should not be used in conjunction with hypoxia.	Absence of sweating.	Post-anesthetic hypotension and delirium; concurrent use of epinephrine may lead to ventricular tachycardia and fibrillation.

/1/ Marketed as Vinethene which has added to it 3.5% alcohol to decrease its rate of vaporization, and 0.01% phenyl- α -naphthylamine as a preservative an improvement over diethyl ether. /3/ Stabilized with 0.01% thymol and tinted (for anesthetic use) to distinguish it from chloroform which has drugs, such as metabolic depressants, autonomic blocking agents, sympathicomimetic agents, endocrines, and muscle relaxants, significantly modify are from consensus of opinion among anesthesiologists. /16/ May be modified by a narcotic, a barbiturate, or a belladonna derivative used in pre- and blood during surgery. Maintenance of body temperatures during surgery is also a factor in fluid shifts from one body compartment to another.

CHEMICAL, PHYSICAL, AND PHYSIOLOGICAL CHARACTERISTICS (Concluded)

impressions and opinions have not been included. Blank spaces indicate unavailability of data.

Volatile Agents						
Diethyl Ether	Divinyl Oxide ¹	n-Propyl Methyl Ether ²	Chloroform	Trichlorethylene ³	Ethyl Chloride	
Physiological Effects ¹⁴ (concluded)						
Present plane 1; fixed plane 2.	Rhythmic activity in light stage III.	Eyeballs may remain eccentric in plane 4.	Strabismus in light planes.	Nystagmus during induction and recovery.	Rotate into plane 3.	27
Dilated stage II, constricted plane 1; dilated plane 3.	Pupillary reflex to light remains active.	Pupils may remain constricted in plane 4.	Dilated in stage II.	Usually constricted in surgical plane.	Dilated in light planes.	28
550% increase in secretion during induction, depressed in surgical plane.	Profuse salivation.	Increased secretion in some patients.	500% increase in secretion during induction.	Not stimulated.	Little secretion.	29
Bromsulphthalein may be retained from 15-30% post-operatively; bile secretion decreased.	No impairment in obstetrics after one hr of anesthesia; no impairment bile secretion; possible liver damage in humans; liver necrosis in dogs.	No histologic damage in dog, rat, and monkey.	Greater retention of bromsulphthalein and higher cephalin flocculation post-operatively than with other agents. Can be markedly damaging, and acute yellow atrophy may occur especially with hypoxia.	Clinically non-toxic; no histologic changes noted.	Jaundice and fatty degeneration noted after repeated administration.	30
21% decrease glomerular filtration, 39% decrease renal plasma flow, 25% increase filtration fraction, 51% decrease urine flow, increased tubular reabsorption.	Oliguria or anuria, with decreased urea clearances in dogs.	No histologic damage in dog, rat, and monkey.	Decrease in urea clearance and changes in other tests similar to those obtained with other agents.	No histologic changes noted.		31
Constricted			Constricted			32
Adrenalin secretion stimulated.	No stimulation of adrenalin secretion.		Effect undecided.			33
Decreased peristalsis, decreased tone, decreased colonic contractions.	Increased tone and decreased peristalsis of stomach; decreased tone and peristalsis of intestines, decreased colonic contractions.		Decreased peristalsis, decreased colonic contractions.		Spasm of colonic muscles.	34
Decreased contractions.	Contractions not decreased.		Marked decrease in strength of contractions.	Little effect.		35
Adequate relaxation; sensitizes myoneural junction to curare.	Adequate relaxation in proper plane.	Excellent relaxation in 2nd plane.	Excellent relaxation.	Usually inadequate relaxation.	Usually inadequate relaxation.	36
Increased with some decrease of plasma volume and increase of red cell mass.			Decreased. ¹⁵			37
Usually decreased but patient poikilothermic.			Decreased.	Decreased.		38
Vasodilatation; in capillaries rapid unrestricted flow and decreased vasomotion.			Vasodilatation.	Constriction of vessels, relatively less capillary bleeding.	Vasodilatation.	39
Sympathicomimetic.	Sympathicomimetic ¹⁵ in some respects.		Sympathicomimetic.	May increase vagal tone.		40
Decreased.			Decreased.			41
Tendency for metabolic acidosis to occur.	Minimal disturbance of acid-base balance.		May result in metabolic acidosis.			42
Convulsions occasionally occur during narcosis probably associated with hypoxia or hypercardia.	Convulsions during induction, maintenance, or recovery in unpremedicated patients. Running movements in dogs.	Overdose produces marked depression of blood pressure.	Sudden death from ventricular fibrillation or arrest may occur during induction.	Convulsions may occur in children under 2 yr, specific anesthesia of 5th cranial nerve.	Ventricular fibrillation may occur during induction.	43

ative. /2/ Included here as an example of a recent product developed in the search for an ideal anesthetic agent, although it has not proved itself to a similar odor. /14/ Those listed presuppose administration of a single agent with adequate oxygen and without accumulation of carbon dioxide. Other these effects. /15/ No data available in the literature, or available data sketchy and based on clinical impression or animal experiments. Statements medication. /17/ These studies were done primarily on animals before literature appeared concerning adequate replacement of fluid, electrolytes,

333. DRUGS AFFECTING THE
The use of certain trade names is for informative purposes only and in no way is intended to imply

Part I: SPECIFIC HEMODYNAMIC

Values are per cent increase or decrease from level before administration of drug and are ranges or averages of effects on groups of subjects included - = decreases; 0 = unchanged; ? = questionable. In some instances drugs are listed with no accompanying data. Other information, however, is present in the column headings: MABP = mean systemic arterial pressure; Car. O = cardiac output; TSVR = total systemic vascular resistance; Cer. BF = limb vessels; RBF = renal blood flow; RVR = renal vascular resistance; Hep. BF = hepatic blood flow; Hep. VR = hepatic vascular resistance; PABP = vessels; Cor. BF = coronary blood flow; Cor. VR = coronary vascular resistance; Car. O₂ = cardiac oxygen uptake; Car. R = cardiac rate; Car. Ex. =

Drug	MABP	Car. O.	TSVR	Cer. BF	Cer. VR	Cer. O ₂	LBF	LELV	RBF
1 Acetazolesamide									
2 Acetylcholine									
3 Aconitine									
4 Alkavervir				-12	-28	+17			
5 Alseroxylon									
6 Ambonestyl									
7 Aminophylline	+7 to +8	+6 to +33	-4 to -19	-25 to -33	+8 to +24	0 to -18			+12 to +30
8 Ammonium chloride			+26 to +44	-21	+23	+5			
9 Amobarbital sodium	-8 to -13	-26							
10 Amphetamine sulfate				-2	+4	+4			
11 Amyl nitrite									
12 Atropine sulfate							+	Dilates	
13 Azamethonium bromide	-8	+23		-8 to +12	-20 to -35	+7 to +10	+	0	0 to -8
14 Azepetine phosphate							+		-7
15 Barium chloride									
16 Benzathine penicillin G									
17 Bishydroxycoumarin									
18 Caffeine and sodium benzoate				-13	+22 to +28	+8 to +9			
19 Calcium chloride									
20 Carbachol	-7	+12	-17						
21 Chloralose									
22 Chlorisondamine dimethochloride							+		
23 Chloroform									
24 Chloroquine diphosphate									
25 Chlorpromazine				-9	-24	+4			
26 Cocaine									
27 Corticotropin				0	0	-14			
28 Cortisone acetate	+	0							
29 Cyanocobalamin				-56	+177	+22			
30 Cyclopentamine									
31 Cyclopropane	0	0	0						
32 Deslanoside									
33 Desoxycorticosterone acetate				-5	+6	-10			
34 Dextran									
35 Dextroamphetamine sulfate									
36 Dibenzamine hydrochloride	-6 to -9	-6 to +28	-4						
37 Digifolin									
38 Digilanid									
39 Digitalis	-5 to +	-2 to +46	-32 to +3	-4	-9	+13			
40 Digoxin									
41 Digoxin	0 to +8	-15 to +29	-28 to +7						+12 to +19
42 Dihydroergocornine methanesulfonate				0 to -8	-12 to -31	-8 to +3	+	Constr.	
43 Dihydroergotamine methanesulfonate	+3	0	+45						
44 β-Dihydrosolasodine									
45 Diphenhydramine hydrochloride									
46 Diphenylhydantoin sodium									
47 1, 1-Dimethyl-4-phenyl-piperazinium I									
48 Dioxyline phosphate									
49 Ephedrine sulfate	+10	+27	-13						
50 Epinephrine bitartrate	+ or -	+33 to +52	-35	-4 to +22	0	-3 to +28	+	Dil/constr.	-10 to -55
51 Erythrityl tetranitrate									
52 Ether	-5	+71 to +100	-44						
53 Ethyl alcohol	0	-5		-18 to +18	-35 to +12	-10 to +16	+	Dilates	
54 Ethyl chloride									
55 α-Fagarine									
56 Gelatin, 6% solution									
57 Gitalin									
58 Glyceryl trinitrate	0	+		-8	-4	-3			
59 Heparin				-3	0	+4			
60 Hexamethonium bromide or chloride	-20 to -35	-46 to +38	-12 to -60	-4 to -42	-11 to -45	-12 to +4	0 or +	0	-59 to +17
61 Histamine diphosphate				0	-30	+6		Dilates	+28
62 Hydergine	-4	0	-5				+	Constr.	-11 to +5
63 Hydralazine	-10 to -41	+27 to +110	-31 to -61				0 or +	Dilates	-30 to +38
64 Hydroxyamphetamine hydrobromide	+30	0	+						
65 Inositol hexanitrate									
66 Insulin			+11 to +16	-6 to -13	-21 to -42				
67 Isoproterenol hydrochloride	+ to -	+26				+	dilates		
68 Kheilin	+5	0/-6							
69 Lanatoside c	+	+							
70 Levarterenol bitartrate	+15 to +30	-6 to +32	+12 to +31	-8 to -21	-8 to +53	-5 to -15	0	Constr.	-47 to +181
71 Lobeline									
72 Magnesium sulfate									-10
73 Mannitol hexanitrate									
74 Mecamylamine hydrochloride									-21
75 Meperidine									
76 Mephentermine sulfate	+	0	+						

/1/ Caffeine citrate.

CARDIOVASCULAR SYSTEM

endorsement by the National Academy of Sciences-National Research Council for use of the drug.

AND CARDIAC EFFECTS

ing hyper-, hypo-, and normotensive persons. Where quantitative data are not available, direction of action is indicated as follows: + = increases; - = decreases; 0 = no effect. The following abbreviations have been employed: Cer. BP = cerebral blood pressure; Cer. VR = cerebral vascular resistance; Cer. O₂ = cerebral oxygen uptake; LBF = limb blood flow; LELV = local effect on pulmonary arterial blood pressure; Pul. BF = pulmonary blood flow; Pul. VR = pulmonary vascular resistance; LEPV = local effects on pulmonary cardiac excitability; Car. RP = cardiac refractory period; Car. CT = cardiac conduction time; Car. Con. = cardiac contractility.

RVR	Hep. BF	Hep. VR	PABP	Pul. BF	Pul. VR	LEPV	Cor. BF	Cor. VR	Car. O ₂	Car. R	Car. Ex.	Car. RP	Car. CT	Car. Con.	
			+ or 0			Constr.	+128	-59		+ or -	+	-	+ or -		1
															2
															3
															4
															5
			+ to -25	+6 to +33	-37 to +4	Dilates	+1 to +76	-		+	-	+		+	6
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			0			+ to -	+20	-		+	-	+		+	10
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333. DRUGS AFFECTING THE

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Part I: SPECIFIC HEMODYNAMIC

Values are per cent increase or decrease from level before administration of drug and are ranges or averages of effects on groups of subjects included - = decreases; 0 = unchanged; ? = questionable. In some instances drugs are listed with no accompanying data. Other information, however, is present in the column headings: MABP = mean systemic arterial pressure; Car. O = cardiac output; TSVR = total systemic vascular resistance; Cer. BF = limb vessels; RBF = renal blood flow; RVR = renal vascular resistance; Hep. BF = hepatic blood flow; Hep. VR = hepatic vascular resistance; PABP = vessels; Cor. BF = coronary blood flow; Cor. VR = coronary vascular resistance; Car. O₂ = cardiac oxygen uptake; Car. R = cardiac rate; Car. Ex. =

Drug	MABP	Car. O	TSVR	Cer. BF	Cer. VR	Cer. O ₂	LBF	LELV	RBF
77 Merraluride sodium									
78 Mercurophylline sodium									
79 Mersalyl sodium		+19							
80 Metaraminol bitartrate	+50	0	+55	-9	+50	-6			-4
81 Methacholine chloride	-7	+29					0	Dilates	
82 Methamphetamine hydrochloride									
83 Methantheline bromide									
84 Methoxamine hydrochloride	+	-30	+						
85 Methoxyphenamine hydrochloride									
86 Methylhexanamine									
87 Morphine									
88 Naphazoline hydrochloride									
89 Nicotine									
90 Nicotinic acid	1(?)	-4		+6	+9	-3	-	Dilates	
91 Nikethamide									
92 Nitrous oxide									
93 Nordefrine									
94 Oenanthyl hydrochloride									
95 Ouabain									
96 Papaverine hydrochloride				+8 to +12	-17 to -22	0 to +4			
97 Parephyllin				-4	+3	+23			-13 to -18
98 Pentaerythritol tetranitrate									
99 Pentamethonium chloride	-11	+29					+	0	
100 Pentobarbital sodium							+	Dilates	
101 Pentolinium tartrate									
102 Phenobarbital sodium									
103 Phenoxylbenzamine hydrochloride				-12	-31	-14	+		+15 to +57
104 Phentolamine HCl or methanesulfonate				0	-21	0	+	Dilates	
105 Phenylephrine hydrochloride	+35	-28	+						
106 Phenylpropanolamine hydrochloride									
107 Phenylpropylmethylamine									
108 Piperoxan hydrochloride									
109 Pituitary extract (posterior)	-2	-2 to -54	-1						
110 Potassium chloride									
111 Potassium thiocyanate									
112 Procaine hydrochloride	- to +2	-2 to +23		-2 to -12	-16 to +8	-3 to -6	+ or -	Dilates	
113 Procaine amide hydrochloride	-17	-11	+5						
114 Procaine penicillin G				+18	-11	+10			
115 Propylhexedrine									
116 Proxoveratrine A and B maleate							0	0	-7 to -25
117 Pyrilamine maleate									
118 Quinacrine hydrochloride									
119 Quinidine gluconate									
120 Quinidine hydrochloride									
121 Quinidine sulfate	0 to -25	0 to -4	- to +4						
122 Rauwolfia									
123 Rescinnamine									
124 Reserpine	0 or -	+ or -		-2	-17	-3			0
125 Roniacol tartrate							0		
126 Scillaren A									
127 Scillaren B									
128 Scopolamine hydrobromide									
129 Serotonin	+	+30	-3						
130 Sodium bicarbonate				+30 to +69	-25 to -39	-6 to +8			
131 Sodium chloride				0 to +12	-6 to -7	0 to -8			+4
132 Sodium cyanide									
133 Sodium lactate									
134 Sodium nitrite	-3 to -5	+10 to +21	-13 to -15						
135 Sodium salicylate	+3	+14							
136 Sodium sulfide									
137 Sodium thiocyanate	0	-18	+						
138 Strophanthin									
139 Succinylcholine chloride									
140 Synephrine									
141 Tetraethylammonium chloride or Br	-5 to -21	-32 to +35	-27 to -28				+	+ or -	
142 Thiamine hydrochloride									
143 Thiopental sodium	-4 to -19	-20 to -25	0 to +4	-25 to +11	-19	0 to -39			
144 Thiouracil				-13	+31	-14			
145 Tolazoline hydrochloride	+8	+28		-12 to +22	-25 to +6	-3	+	Dilates	
146 Trichlorethylene									
147 Triethanolamine trinitrate BiPO ₄									
148 Trimetaphen camphorsulfonate	-5 to -38	-18 to -19	-8 to -22						0 to -18
149 Trimethadione									
150 Tripelethamine hydrochloride									
151 Tuaminoheptane sulfate									
152 Tubocurarine chloride								Dilates	
153 Urethane									

AND CARDIAC EFFECTS (Continued)

[illegible]

333. DRUGS AFFECTING THE

The use of certain trade names is for informative purposes only and in no way is intended to imply

Part I: SPECIFIC HEMODYNAMIC

Values are per cent increase or decrease from level before administration of drug and are ranges or averages of effects on groups of subjects included - = decreases; 0 = unchanged; ? = questionable. In some instances drugs are listed with no accompanying data. Other information, however, is present in the column headings: MABP = mean systemic arterial pressure; Car. O = cardiac output; TSVR = total systemic vascular resistance; Cer. BF = limb vessels; RBF = renal blood flow; RVR = renal vascular resistance; Hep. BF = hepatic blood flow; Hep. VR = hepatic vascular resistance; PABP = vessels; Cor. BF = coronary blood flow; Cor. VR = coronary vascular resistance; Car. O₂ = cardiac oxygen uptake; Car. R = cardiac rate; Car. Ex. =

Drug	MABP	Car. O	TSVR	Cer. BF	Cer. VR	Cer. O ₂	LBF	LELV	RBF
154 Urganin									
155 Veratramine									
156 Veratridine									
157 Veratrone	-11 to -14	0	-6 to -21				-	0	-
158 Vergitryl									
159 Vertavis									
160 Vinyl ether									

Part II: SITES OF ACTION

Numbers in brackets refer to drugs listed in Part I.

Site of Action	Stimulant Drugs	Depressant Drugs	Site of Action	Stimulant Drugs	Depressant Drugs
NERVOUS MECHANISMS CONTROLLING CIRCULATION			NERVOUS MECHANISMS CONTROLLING CIRCULATION (Concluded)		
Central Nervous System (Direct Action)			Autonomic Nervous System		
1 Vasoconstrictor center	Analeptics [18, 91] ¹ .	General anesthetics [23, 31, 52, 54, 92, 143, 146, 160] ¹ .	9 Sympathetic ⁷ and parasympathetic ⁸ ganglia	Ganglion stimulants [89].	Ganglion-blocking agents [13, 22, 60, 74, 99, 101, 141, 148]; high concentration of nicotine [89].
2 Cardioaccelerator center					
3 Cardioinhibitory center ²	General anesthetics [23, 31, 52, 54, 92, 143, 146, 160] ¹ .	Analeptics [18, 91] ¹ .	10 Post-ganglionic nerve terminations: sympathetic ⁷	Sympathomimetics [10, 30, 35, 49, 50, 64, 70, 76, 80, 82, 84, 86, 88, 93, 94, 102, 105, 106, 115, 140, 151].	Adrenergic blocking drugs [13, 22, 60, 74, 99, 101, 141, 148].
4 Other areas, unidentified	None recognized.	Rauwolfia alkaloids [5, 122, 123, 124]; hydralazine [63]; morphine [87].			
Sensory Receptors in Heart, Lungs, and Blood Vessels					
5 Stretch receptors in carotid sinuses and aortic arch ³	Activated indirectly, and by local application of sympathomimetics [10, 30, 35, 49, 50, 64, 70, 76, 80, 82, 84, 86, 88, 93, 94, 102, 105, 106, 115, 140, 151]; veratrum alkaloids [4, 116, 157, 158, 159].	Local anesthetics [112]; receptors inactivated indirectly by hypotensive drugs [2, 7, 11, 20, 48, 51, 53, 58, 65, 68, 73, 81, 96, 97, 98, 134, 147].	11 Post-ganglionic nerve terminations: parasympathetic ⁸	Parasympathomimetics [2, 20, 81].	Parasympathetic blocking agents [12, 83, 128].
			MUSCULAR COMPONENTS OF CIRCULATORY SYSTEM		
			Smooth Muscle of Blood Vessels		
			12 With specific antagonist	Methacholine [81].	Atropine [12].
			13 Without specific antagonist	Histamine [61].	Antihistamines [45, 117, 152].
			14 Without specific antagonist	Musculotropic vasoconstrictors [109, 129].	Musculotropic vasodilators [7, 11, 48, 51, 53, 58, 65, 68, 73, 96, 97, 98, 134, 147].
			Heart		
6 Chemoreceptors in carotid and aortic bodies ⁴	Ganglion stimulants [89]; oxidation inhibitors (e.g., cyanide, sulfide) [132]; papaverine [96]; nikethamide [91]; aminophylline [7].	Local application of ganglionic blocking agents [13, 22, 60, 74, 99, 101, 141, 148] depresses action of ganglion stimulants; oxygen inhalation depresses action of cyanide.	15 Contractility of heart muscle	Digitalis glycosides [32, 37, 38, 39, 40, 41, 57, 69, 95, 126, 127, 138, 154].	Quinidine [121]; general anesthetics [23, 31, 52, 54, 92, 143, 146, 160].
7 Stretch receptors in heart, lung parenchyma, blood vessels ⁵	Veratrum alkaloids [4, 116, 157, 158, 159].	Local anesthetics [112].	16 Excitability of the heart	Profibrillatory drugs: chloroform [23]; cyclopropane [31].	Antifibrillatory drugs [6, 113, 119, 120, 121]; quinidine [121].
8 Various receptors in respiratory passages and joints ⁶	Veratrum alkaloids [4, 116, 157, 158, 159]; low concentration of volatile anesthetics [23, 52, 160].	High concentration of volatile anesthetics [23, 52, 160].	/1/ None selective. /2/ Reciprocal innervation with cardioaccelerator center. /3/ Type 1 receptors producing perfect inhibition of vasoconstrictor, cardioaccelerator, and respiratory centers. /4/ Type 3 receptors producing pure stimulation of vasoconstrictor, cardioaccelerator and respiratory centers. /5/ Type 2 receptors producing imperfect inhibition of vasoconstrictor, cardioaccelerator and respiratory centers. /6/ Type 4 receptors producing impure stimulation of vasoconstrictor, cardioaccelerator and respiratory centers. /7/ Sympathetic stimulation causes cardiac acceleration and constriction of most blood vessels (peripheral). /8/ Parasympathetic stimulation causes cardiac slowing and dilatation of most blood vessels.		

CARDIOVASCULAR SYSTEM (Continued)

endorsement by the National Academy of Sciences-National Research Council for use of the drug.

AND CARDIAC EFFECTS (Concluded)

ing hyper-, hypo-, and normotensive persons. Where quantitative data are not available, direction of action is indicated as follows: + = increases; - = decreases; 0 = no effect. The following abbreviations have been employed: Cer. O₂ = cerebral oxygen uptake; LBF = limb blood flow; LELV = local effect on cerebral blood pressure; Cer. VR = cerebral vascular resistance; Cer. O₂ = cerebral oxygen uptake; LBF = limb blood flow; LELV = local effect on cerebral blood pressure; Pul. BF = pulmonary blood flow; Pul. VR = pulmonary vascular resistance; LEPV = local effects on pulmonary arterial blood pressure; Car. RP = cardiac refractory period; Car. CT = cardiac conduction time; Car. Con. = cardiac contractility.

RVR	Hep. BF	Hep. VR	PABP	Pul. BF	Pul. VR	LEPV	Cor. BF	Cor. VR	Car. O ₂	Car. R	Car. Ex.	Car. RP	Car. CT	Car. Con.	
-	-	-	-10 to -29			0				-					154
															155
															156
															157
															158
															159
														-	160

Part III: "CARDIOVASCULAR DRUGS": USES AND EFFECTS

"Cardiovascular Drugs," for the purposes of this table, refers to those drugs used primarily in treatment of circulatory system disorders. Numbers in brackets refer to drugs listed in Part I.

Drug Number, Synonyms, Trade Names		Route of Administration ¹	Effects: Desirable (D); Undesirable (U)	Drug Number, Synonyms, Trade Names		Route of Administration ¹	Effects: Desirable (D); Undesirable (U)
ANTIHYPERTENSIVE DRUGS ²				VASODILATORS ¹¹ (concluded)			
Veratrum Alkaloids				Musculotropic Vasodilators			
1	[4] ³ , Veriloid	PO, IM, IV	D: hypotension.	31	[1]	IH	D: subjective relief of
2	[116] ⁴ , Provell	PO	U: severe bradycardia,	32	[58], Nitroglycerine	SL	angina.
3	[157] ⁵ , 158 ⁵ , 159 ⁶	PO	nausea, vomiting, salivation, sweating.	33	[134]	PO	U: syncope, methemo-
Rauwolfia Alkaloids				34	[73]	PO	globinemia, develop-
4	[124] ⁷ , Serpasil, Serpiloid, Reser- poid, Raused, Serpate	PO	D: hypotension. U: mental depression, nasal congestion, nausea, brady- cardia, weakness, fatigue.	35	[98], Peritrate	PO	ment of tolerance.
5	[123] ⁸		36	[51]	PO		
6	[122] ⁹ , Raudixin, Rauwal		37	[65]	PO		
7	[5] ¹⁰ , Rauwiloid, Rau- tension, Rau-Tab, Rauwistan		38	[147], Metamine	PO		
			39	[7], Theophylline ethylenediamine	PO, IM, IV		U: variable effects on coronary and limb blood flow; inconstant clinical results.
				40	[97], Soluphylline	IM	
				41	[96]	IV, IM	
				42	[48], Paveril	PO	
				43	[68], Eskel	PO	
				44	[53], grain alcohol	PO	
Miscellaneous				HYPERTENSIVE DRUGS ¹³			
8	[63], Apresoline	PO	U: nausea, constipation.	Sympathomimetic Amines: Systemic Pressure Action			
9	[111] (or sodium salt)	PO	U: drowsiness, vomiting.	45	[50], Adrenaline, Suprarenin	SC, IV	D: rise in systemic arterial pressure.
VASODILATORS ¹¹				46	[70], Levophed, Nor- adrenaline	IV	U: some amines induce cardiac arrhythmias and cerebral excitation.
Ganglionic Blocking Drugs				47	[49]	PO, SC, IM	
10	[141], Etamon	IV, IM	D: Increased blood flow to limbs; lowering of arterial pressure if hypertensive.	48	[64], Paredrine	IM, TOP	
	[60], Bistrium, Methium, Estomid, Hexameton, Hiohax	PO, IV, SC		49	[76], Wyamine	IM, IV, TOP	
12	[99]	IV	U: severe hypotension (unless intentional for hypertensive surgery; generalized ganglion blockade manifested by blurring of vision, dry- ness of mouth, tachy- cardia, constipation).	50	[82], Methedrine, Des- oxyephedrine, Desoxin, Dexoval, Droxlyfed, Eroxine, Norodin	PO, SC, IM, IV, TOP	
13	[13], Pendiomide	IV		51	[84], Vasoxyl	IM	
14	[22], Ecolid	PO		52	[105], Neosynephrine	SC, IM, IV	
15	[74], Inversine				Isophrin	TOP	
16	[101], Ansolsen, Pentapyrrolidinium	PO		53	[30], Clopane	IV, IM, TOP	
17	[148], Arfonad	IV		54	[94]	IV, IM	
Adrenergic Blocking Drugs				55	[140], Sympatol, Synthenate	SC, IM	
18	[104], Regitine	PO, IV, IM	D: increased blood flow to limbs; hypotensive action useful in diag- nosis of pheochromo- cytoma.	Sympathomimetic Amines: Local Application			
19	[108], Benodaine	IV		56	[10], Benzadrine, Actedrow	IH	D: local nasal decon- gestion. (With the excep- tion of drugs [10] and [35], which fall in the same general category as [82], these amines are too toxic for parenteral use.)
20	[43]	IV, IM		57	[35], Dexedrine	TOP	
21	[42]	IV, IM		58	[88], Privine	TOP	
22	[62] ¹²	SL, IV, IM		59	[115], Benzedrex	IH	
23	[14], Ilidar	PO, IV	U: drowsiness, nausea, vomiting, tachycardia, nasal congestion.	60	[151], Tuamine	IH, TOP	
24	[36]	IV		61	[106], Propadrine	TOP	
25	[103], Dibenzylamine	IV, PO		62	[107], Vonedrine	IH, TOP	
26	[125]	PO		63	[80], Aramine	TOP	
27	[145], Priscofine	PO, IV		64	[86], Forthane	IH	
Cholinergic Vasodilators				65	[93], Cobefrine	TOP	
28	[2]	IM, SC	U: peripheral vasodila- tion accompanied by generalized parasymp- athomimetic actions.				
29	[81], Mecholyl	SC					
30	[20], Doryl	SC					

/1/ PO = oral; IM = intramuscular; IV = intravenous; SC = subcutaneous; SL = sublingual; IH = inhalation; TOP = topical. /2/ For acute and chronic relief of essential and other forms of systemic hypertension. /3/ Mixture of alkaloids extracted from Veratrum viride. /4/ From Viscum album. /5/ Partially purified extract of Veratrum viride. /6/ Whole powdered preparation of V. viride. /7/ From Rauwolfia serpentina. /8/ Purified alkaloid. /9/ Powdered root of R. serpentina. /10/ Alkaloidal mixture from alseroxylon fraction of Rauwolfia extract. /11/ For improving blood flow in diseased limb and coronary vascular beds; for relief of systemic hypertension. /12/ Equal parts of dihydroergocornine-, dihydroergocristine-, and dehydroergokryptine methanesulfonates. /13/ Exert pressor action for correction of hypotensive states; local vasoconstrictor action for nasal decongestion.

333. DRUGS AFFECTING THE CARDIOVASCULAR SYSTEM (Concluded)

The use of certain trade names is for informative purposes only and in no way is intended to imply endorsement by the National Academy of Sciences-National Research Council for use of the drug.

Part III: "CARDIOVASCULAR DRUGS": USES AND EFFECTS (Concluded)

"Cardiovascular Drugs", for the purposes of this table, refers to those drugs used primarily in treatment of circulatory system disorders. Numbers in brackets refer to drugs listed in Part I.

Drug Number, Synonyms, Trade Names	Route of Administration ¹	Effects: Desirable (D); Undesirable (U)	Drug Number, Synonyms, Trade Names	Route of Administration ¹	Effects: Desirable (D); Undesirable (U)
CARDIOTONIC DRUGS¹⁴			CARDIOTONIC DRUGS¹⁴ (concluded)		
Digitalis Purpurea Glycosides		D: improve ventricular function of heart in failure with and without auricular fibrillation; A-V block.	Urginea maritima (Squill) Glycosides		Same as for Items 66-72.
66 [37, 39, 40, 57]	PO		73 [126, 154]	PO	
67 [41]	PO, IV		74 [127]	IV	
Digitalis Lanata Glycosides			ANTIARRHYTHMIC DRUGS¹⁵		
68 [69], Cedilanid	PO		Cinchona Alkaloids		
69 [38]	PO, IV	U: anorexia, vomiting, headache, ventricular arrhythmia; excessive A-V block.	75 [121]	PO	D: antibrillatory action.
70 [32], Cedilanid D	IV		76 [119]	IM	U: cinchonism; vascular collapse following IV.
Strophanthus Gratus, S. Kombe Glycosides			77 [120]	IM, IV	
71 [95], Strophanthin G	IV		Synthetics		
72 [138]	IV		78 [113], Pronestyl	PO, IV	U: Depression of cardiac muscle contractility; hypotension.
			79 [6]	IV	

/1/ PO = oral; IM = intramuscular; IV = intravenous; SC = subcutaneous; SL = sublingual; IH = inhalation; TOP = topical. /14/ For management of congestive heart failure. /15/ For prophylactic and curative control of cardiac arrhythmia.

Part IV: "NON-CARDIOVASCULAR DRUGS": USES AND EFFECTS

"Non-cardiovascular Drugs," for the purposes of this table, refers to those drugs used primarily in treatment of disorders other than those of the cardiovascular system. Numbers in brackets refer to drugs listed in Part I.

Drug Number	Use in Clinical Disorder of Circulatory System	Nature of Cardiovascular Action	Drug Number	Use in Clinical Disorder of Circulatory System	Nature of Cardiovascular Action
Analeptics			Hypnotics and Sedatives		
1 [91]	Stimulant to vasomotor and respiratory centers.	Direct effects (?) on heart and coronaries.	16 [9, 100, 102]	Sedative in hypertension and heart disease.	In large doses, depressant to cardiac contraction.
2 [18]		Direct stimulation of heart muscle and vasodilatation.	Ions		
Analgesics			17 [8, 15, 19, 72, 110, 130, 133]	Limited clinical trial as antiarrhythmic or as stimulants to arrested ventricles.	Alterations in excitability and automaticity of heart.
3 [125]	Antipyretic for rheumatic carditis.	Claimed to have direct effect on cardiac lesion.	Neuromuscular Blocking Agents		
4 [75, 87]	Sedative for acute myocardial infarction or acute congestive failure.	In large doses, vasomotor depression and bradycardia.	18 [139, 152]	None.	Curare preparations cause hypotension through histamine liberation, ganglionic blockade, and decreased muscle tone.
Anesthetics, General			Parasympathetic Blocking Drugs		
5 [23, 31, 52, 54, 92, 143, 146, 160]	None directly. Cardiac patients may be subjected to general anesthetics if necessary.	Depressant to cardiac contraction. In general, all are vasodilators. [23, 31] can cause dangerous cardiac arrhythmias.	19 [12, 83, 128]	Diagnosis and treatment of cardiac arrhythmia by virtue of increased vagal tone; antidote for anticholinesterase poisoning.	Cardioaccelerator.
Anesthetics, Local and Spinal			Plasma Extenders		
6 [26, 112]	Applied locally to exposed heart to prevent arrhythmia during cardiac surgery.	Spinal anesthesia may reduce arterial blood pressure by sympathetic blockade and decreased thoracic movement.	20 [34, 56, 131]	Plasma expander in shock.	Increased cardiac output.
Antibiotics			Sympathomimetic Bronchodilators		
7 [16, 114]	Control of subacute bacterial endocarditis.	Secondary to arrest of infectious process.	21 [67, 85]	Relief of bronchial asthma.	Hypotension. Action unlike that of sympathomimetic amines [30, 49, 50, 64, 70, 76, 82, 84, 94, 105, 140].
Anticoagulants			Tranquilizers		
8 [17, 59]	Prophylaxis against thromboembolic diseases.	Prevention of thromboses and emboli.	22 [25]	Prevention of nausea in uremia, eclampsia, and veratrum therapy and relief of mental aberrations.	Essentially secondary to actions on nervous system.
Anticonvulsants			Vitamins		
9 [46, 149]	None	Antiarrhythmic activity.	23 [29]	None.	None.
Antihistaminics			24 [90]	Treatment of peripheral vascular disease.	Vasodilator(?).
10 [45, 117, 150]	None.	Antibrillatory action demonstrated in animals.	25 [142]	Treatment of cardiac beri-beri.	None, unless deficiency symptoms exist.
Antimalarials			Miscellaneous¹		
11 [24, 118]	Antibrillatory agent.	Decreased excitability of cardiac muscle.	26 [3]	None because of toxicity.	Proarrhythmic.
Anti-thyroids			27 [61]		Vasodilator.
12 [144]	Treatment of hyperthyroid heart disease.	None directly.	28 [129]		Vasoconstrictor.
Diuretics			29 [47, 71, 89]		Ganglion stimulant.
13 [1, 77, 78, 79]	Mobilization of sodium ion and water in congestive heart failure.	Decreased blood volume aids in treating congestive heart failure. In large doses is depressant to cardiac muscle.	30 [55]		Antiarrhythmic.
Endocrine Preparations			31 [44, 155]		Antiaccelerator.
14 [27, 28, 33, 66]	None.	None.	32 [132, 136]		Chemoreceptor stimulant.
15 [109]		Vasoconstrictor.	33 [156]		Visceral receptor stimulant.
			34 [21, 153]		General anesthetic.

/1/ For animal experimental use.

334. VERTEBRATE HORMONES: PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS

Part I: PHYSICAL AND CHEMICAL CHARACTERISTICS

† = decreased; ‡ = increased.

Name, Synonyms, Chemical Formula (Systematic Name)	Properties ¹	Sources ¹	Assay Methods	Metabolites
Adrenal Cortex				
1 Aldosterone; electrocortin; C ₂₁ H ₂₈ O ₅ (Δ ⁴ -pregnen-18-al-11β, 21-diol-3, 20-dione-11, 18-hemi-acetal)	MW=360; MP=164; [α] _D ²⁰ =+160°(chl.); s. org. solv.; sl. s.w.	Adrenals (beef, hog, dog, monkey); human urine, placenta (?).	Urinary Na:K ratio in adre-x rats; recovery muscle fatigue (Everse and de Fremery test) in adre-x rats; muscular work performance (Ingle's test) in adre-x rats; deposition of liver glycogen (rats, mice); weight maintenance in adre-x dogs; survival and growth (Kuizenga test) in young adre-x rats; prevention of convulsions (anti-insulin test) in mice; protection against cold in adre-x rats; decrease in circulating eosinophils, circulating lymphocytes, thymus weight; chemical methods (formaldehydogenic, reducing properties, reaction with phenylhydrazine).	Unknown.
2 Desoxycorticosterone=DOC; acetate = DOCA or DCA; C ₂₁ H ₃₀ O ₃ (Δ ⁴ -pregnen-21-ol-3, 20-dione)	MW=330; MP=141-142; [α] _D ²⁰ =+178°(al.); s. acet., bz., chl., vol. solv., veg. oils; i.w.	Adrenal cortex; synth. commercially from cholesterol, diosgenin.		Pregnanediol; 17-ketosteroids; 17-OH-steroids (?).
3 Corticosterone; C ₂₁ H ₃₀ O ₃ (Δ ⁴ -pregnen-11β, 17α-21-triol-3, 20-dione)	MW=346; MP=180-182; [α] _D ²⁰ =+262°(al.); s. org. solv.; sl. s. veg. oils; v. sl. w.	Adrenal cortex; purine synth. from desoxycholic acid.		17-Ketosteroids (11-OH-androsterone and 11-ketotiocholol-3-(a)-ol-17-one. Similar to those of corticosterone; 11-keto-pregnenediol main metabolite.
4 Dehydrocorticosterone; cortexone; C ₂₁ H ₂₈ O ₄ (Δ ⁴ -pregnen-21-ol-3, 11, 20-trione)	MW=344; MP=178-180; [α] _D ²⁰ =+258(al.); s. org. solv.; i.w.			
5 Hydrocortisone; 17-hydroxycortisone; cortisol; C ₂₁ H ₃₀ O ₅ (Δ ⁴ -pregnen-11β-17α-21-triol-3, 20-dione)	MW=362; MP=217-220; [α] _D ²⁰ =+167°(al.); s. chl., eth., veg. oils; sl. s.w.	Adrenal cortex; synth. from desoxycholic acid.		Similar to those of corticosterone (17-ketosteroids); cortisone (?).
6 Cortisone; 17-OH-11-dehydrocorticosterone; C ₂₁ H ₂₈ O ₅ (Δ ⁴ -pregnen-17α-21-diol-3, 11, 20-trione)	MW=360; MP=220-224; [α] _D ²⁰ =+209°(al.); s. acet., chl., bz., eth., veg. oils; sl. s.w.			17-Ketosteroids, in small quantities.
7 Fluorocortisone; C ₂₁ H ₂₉ O ₅ F (9-a-Fluoro-17β-[1-keto-2-hydroxyethyl]-Δ ⁴ -androstene-3, 11-dione-17a-ol)	MW=380; MP=233-234(acetate); [α] _D ²³ =+123°(acetate).	Synthetic.		
Ovaries				
8 Equilenin; C ₁₈ H ₁₈ O ₂ (Δ ^{1,3,5:10,6,8} -estrapien-3-ol-17-one)	MW=266; MP=258-259; [α] _D ²⁰ =+89°(diox.); s. vol. solv.; sl. s. al., veg. oils; i.w.	Synth.; 4 stereoisomers; natural estrogen from pregnant mare urine.		One inactive stereoisomer is produced by catalytic dehydrogenation of estrone. Easily dehydrogenated to equilenin.
9 Equilin; C ₁₈ H ₂₀ O ₂ (Δ ^{1,3,5:10,7} -estrapien-3-ol-17-one)	MW=268; MP=238-240; [α] _D ²⁰ =+308°(diox.); s. vol. solv.; sl. s. veg. oils; i.w.	Pregnate mare urine.	Colorimetric: phenolsulfonic acid (Kober); ZnCl ₂ /benzoyl Cl, sulfanilic acid/NaNO ₂ (Pincus); spectrophotometric; estrus changes in vagina (immature rats, mice, Allen-Doisy).	β-estradiol
10 β-Estradiol; dihydro[1-theelin, -folliculin, -estrone]; di-OH-estrin; C ₁₈ H ₂₄ O ₂ (3, 17β-di-OH-1, 3, 5, 10-estratriene)	MW=272; MP=178; [α] _D ²⁰ =+82°(diox.); s. alk., vol. solv.; sl. s. veg. oils; i.w.	Urine (pregnant mare, rabbit, man); ovary (swine); testes (stallion); human placenta; synth. from cholesterol.		estrone ↔ α-estradiol
11 Estrinol; theelin; tri-OH-estrin; C ₁₈ H ₂₄ O ₃ (Δ ^{1,3,5:10} -estratriene-3, 16a, 17β-triol)	MW=288; MP=282; [α] _D ²⁰ =+53-63°(diox.); s. vol. solv., alk.; sl. s. veg. oils; i.w.	Urine (pregnant ?); placenta; synth. from estrone, β-estradiol.		estrinol (principal metabolite in urine; excreted as water-soluble inactive glucuronide).
12 Estrone; theelin; folliculin; keto-OH-estrin; C ₁₈ H ₂₄ O ₂ (Δ ^{1,3,5:10} -estratrien-3-ol-17-one)	MW=270; MP=255; [α] _D ²⁰ =+170°(diox.); s. vol. solv., alk.; v. sl. s.w.; sl. s. veg. oils.	Adrenal cortex; urine (man, bull, steer); synth. from cholesterol, diosgenin.		
13 Progesterone; progestin; luteosterone; C ₂₁ H ₃₀ O ₂ (Δ ⁴ -pregnen-3, 20-dione)	MW=314; MP(α)=128, (β)=121; [α] _D ²⁰ =+172-182°(diox.); s. vol. solv.; sl. s. veg. oils; i.w.	Corpus luteum, placenta, adrenal cortex; synth. from cholesterol or stigmasterol.		Pregnanediol.
14 Relaxin	Polypeptide (?); IEP=5.5; s. w. and 95% al.	Serum (pregnant ?); placenta; corpus luteum.	Degree of relaxation of pelvic ligaments (guinea pig).	Unknown.
Placenta				
15 Chorionic gonadotropin ² (HCG; prolan)	MW(HCG)=60,000-80,000; MW(PMS)=30,000(?); IEP(HCG)=3.2; IEP(PMS)=2.6; s.w., 50% acet., 60% al.; inactivated pH 2.0.	HCG-placenta, urine (pregnant woman; PMS-placenta; blood (pregnant mare).	Corpus luteum formation (mice); ovarian wt. (rat); ovulation (rabbit); repair ovarian cells (immature hypophysectomized rats).	HCG excretion; basis of Aschheim-Zondek pregnancy test.
Testes (and Androgens from Urine)				
16 Testosterone; C ₁₉ H ₂₈ O ₂ (Δ ⁴ -androstene-17β-ol-3-one)	MW=288; MP=155-156; [α] _D ²⁰ =109°(al.); absorption maximum = 238 mμ; s. al., eth., vol. solv.; sl. s. veg. oils; i.w.	Testes (bull); synth. from cholesterol and dehydroandrosterone.	17-Ketosteroids (urine) ³ ; alk. m-dinitrobenzene; SbCl ₃ -acetic anhydride (colorimetric); chromatography; capon comb growth; blackening of bill (sparrow); †wt. seminal vesicle, prostate (castrated rats).	Androsterone; etiocholanolone.
17 Dehydroepiandrosterone; dehydroisoandrosterone; C ₁₉ H ₂₈ O ₂ (Δ ⁵ -androstene-3β-ol-17-one)	MW=288; MP(leaflets) 152-153; [α] _D ²⁰ =+10.9°(al.); s. al., eth., bz., precipitated by digitonin; i.w.	Urine (man, bull, pregnant cow); synth. from cholesterol.		Found only in urine in conjugated form.
18 Androsterone; C ₁₉ H ₃₀ O ₂ (androstane-3-(a)-ol-17-one)	MW=290; MP=185.5; [α] _D ²⁰ =+87.8°(diox.); s. vol. solv.; sl. s. veg. oils; not precipitated by digitonin; i. w.	Urine (man, bull, pregnant cow); synth. from cholesterol or sitosterol.		Found only in urine (probably a metabolite of testosterone).
19 Pregnenolone; C ₂₁ H ₃₂ O ₂ (Δ ⁵ -pregnen-3(β)-ol-20-one)	MW=316; MP=193; [α] _D ²⁰ =+28°(al.); s. chl., al., diox.; v. sl. s.w.	Testes (hog); synth. from stigmasterol, diosgenin and cholesterol.	None available.	Pregnanediol.

/1/ ac. = acid; acet. = acetone; al. = alcohol (ethanol, 95%); alk. = alkali; aq. = aqueous; bz. = benzene; chl. = chloroform; diox. = dioxane; eth. = ether; HCG = human chorionic gonadotropin; i. = insoluble; IEP = isoelectric point; me. al. = methyl alcohol; MP = melting point; MW = molecular weight; org. = organic; PMS = pregnant mare serum; pptd. = precipitated; s. = soluble; sl. = slightly; sol. = solution; solv. = solvents; synth. = synthesized; v. = very; vol. = volatile; w. = water; wt. = weight; -x = -ectomized (e.g., hypo-x = hypophysectomized). /2/ Placenta also produces estrogens and progesterone. /3/ Not applicable to testosterone.

334. VERTEBRATE HORMONES: PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS (Continued)

Part I: PHYSICAL AND CHEMICAL CHARACTERISTICS (Concluded)

↓ = decreased; ↑ = increased.

Name, Synonyms, Chemical Formula (Systematic Name)	Properties ¹	Source ¹	Assay Methods	Metabolites
Anterior Pituitary				
20 Adrenocorticotropin; adrenotropin; adrenocorticotrophic hormone; corticotropin; ACTH	MW=4500; IEP=4.7-4.8; Sed ₂₀ ² =2.08; s. w.; 60-70% al.; basic polypeptide(s).	Anterior pituitary (especially sheep, ox, swine).	Adrenal repair, wt. maintenance (hypo-x rats); adrenal ascorbic acid (hypo-x rats); urinary excretion of corticoids (guinea pig).	
21 Follicle-stimulating hormone; thylenkentrin; FSH	IEP=4.8; stable pH 7-8, 30 min at 75°; s. w., 50% acet., 70% al., 50% diox., 1/2 saturated (NH ₄) ₂ SO ₄ .	Anterior pituitary (especially sheep, swine); urine (castrates); PMS.	Follicular growth (hypo-x rats); weight, ovary and uterus (hypo-x immature ♀ rats); ↑ uterine weight (immature mice).	
22 Growth hormone; somatotropin; GH	IEP=6.85; Diff ₂₀ ² =7.15x10 ⁻⁷ ; visc. coeff.=7.64; s. salt sol.; sl. s. w.; HNO ₃ and acetylation destroy.	Anterior pituitary (various species).	↑ tail length, tibial epiphyseal cartilage (hypo-x rats); body growth (hypo-x rats).	
23 Interstitial-cell-stimulating hormone; luteinizing hormone; ICSH; LH	Sheep: Sed ₂₀ ² =3.6x10 ⁻¹³ ; IEP=4.6 Swine: Sed ₂₀ ² =6.8x10 ⁻¹³ ; IEP=7.45 s. w.; 40% al., dilute salt solution.	Anterior pituitary (especially sheep, swine).	Repair interstitial cells; (hypo-x rats or mice); ↑ wt. ventral prostate (hypo-x rats); ↑ testes wt. (pigeon).	
24 Lactogenic hormone; luteotropin; galactin; prolactin; LTH	Diff ₂₀ ² =9x10 ⁻⁷ ; IEP=5.5-5.73; visc. coeff.=6.65 [α] _D ^{25°} = -40.5°; s. acid, al., me. al.; sl. s. w., dil. salt sol.	Anterior pituitary (especially ox, sheep); urine, in small amounts.	↑ wt. crop sac, proliferation crop gland (pigeon); ↑ milk secretion (rabbit).	
25 Thyrotropic hormone ⁴ ; thyrotropin; thyrotrophic hormone; TSH	Inactivated by boiling, cysteine, ketene, trypsin, pepsin, chymotrypsin; non-diffusible.	Probably anterior pituitary (basophilic cells).	↑ I ₂ thyroid (chicks); ↑ thyroid cell height (chicks); ↑ wt. thyroid gland (guinea pig).	
Pituitary Intermediate Lobe				
26 Intermedin; "B"-hormone; middle lobe hormone; melanophore-expanding hormone	IEP=4.1; dialyzable; moderately heat stable; destroyed by trypsin; stable acid, alk.; s. w.; i. eth., acet.	Intermediate lobe (animals changing skin color); anterior lobe (birds, porpoise).	Melanophore expansion (S. African clawed frog); ↑ BP (chicken).	
Posterior Pituitary				
27 Oxytocic hormone; oxytocin; pitocin; postlobin-O; posterior-lobe principle	IEP=7.7; not adsorbed on charcoal; destroyed by acid, trypsin, tyrosinase; s. w., concentrated acetic acid, me. al.	Posterior pituitary.	Contraction, isolated uterus (guinea pig); ↑ BP (chicken).	
28 Vasopressin; vasopressor principle; postlobin-V; vasopressor-antidiuretic principle; ADH; pitressin	IEP=10.8; adsorbed charcoal; inactivated by trypsin, not pepsin; solubility ≈ to oxytocin.		↑ BP (rat, dog); anti-diuretic activity (rats).	ADH-like material.
Parathyroid				
29 Parathormone; PTH	IEP=5.6; inactivated by proteases, alk.; stable dilute acid; s. w., saline, aq. al., 94% acetic acid, conc. phenol; 50% glycerol; i. vol. org. solv.	Parathyroids.	Rate and degree of rise in serum Ca ⁺⁺ and decrease in serum phosphate (dogs).	
Thyroid				
30 Thyroid hormone ⁵ ; thyroxine; C ₁₅ H ₁₁ O ₄ N ₄ ; p-[(3,5-diiodo-4-OH-phenoxy)-3,5-diiodophenyl]-alanine	MW=777; needles; MP=232-233; [α] _D ^{25°} = 3.2° (NaOH); s. alk. w., alk. or acid al.; i. w., al., vol. solv.	Thyroid gland; synth. from p-methoxyphenol and 3,4,5-triiodonitrobenzene.	↑ BMR, thyroid-deficient subject; limb bud growth, amphibian larvae; ↑ O ₂ consumption.	Inactive iodinated compounds in bile; iodides.
Pancreas				
31 Insulin	MW=36,000 ⁶ ; MP=223; IEP=5.3; s. w., al.; pptd. by protein precipitants; stable acid; destroyed by alk.	Islets of Langerhans (various species).	Convulsions, (mice); hypoglycemia (starved rabbit); ↑ blood glucose (adrenodemedullated, hypo-x, diabetic rats).	
Adrenal Medulla				
32 Epinephrine; adrenalin, suprarenine, adrenine	MW=183; MP(L)=207-211; [α] _D ^{25°} = -50° to -53.5°; s. alk. ac.; sl. s. w.; v. sl. s. al.; i. eth., chl.	Adrenal medulla; synth. (comm.) catechol; in vivo, tyrosine; methylation of nor-epinephrine.	Stimulation isolated heart (frog); relaxation uterus (cat); dilatation pupil (cat); ↑ peristalsis (rabbit); ↑ BP (cat).	Catechol derivatives.
33 Nor-epinephrine; arterenol, nor-adrenalin	MW=169; MP=(L-bitart.)=163-164, L-HCl=146-147; solubility ≈ to epinephrine.	Adrenal medulla; various nerves, especially splenic; spleen, heart, blood vessels.	↑ epinephrine in all tests except pressor and contraction of gravid uterus.	Methylated to epinephrine by adrenals in presence of ATP.
Gastrointestinal Tract				
34 Cholecystikinin; CCK	MW=5,000-10,000(?); IEP=5.0-5.5; dialyzable, s. w.	Upper intestinal mucosa.	Contraction of gall-bladder (dog).	Metabolized as protein(?).
35 Enterocrinin	s. ac., w., al.; i. eth., acet.; salted out by NaCl.	Intestinal mucosa (hog, cat, dog, cow, man).	↑ flow of intestinal juice in jejunum (dog).	
36 Enterogastrone	s. w.; i. org. solv.; dialyzable; destroyed by pepsin.	Duodenal mucosa.	↑ stim. effect of exogenous histamine on HCl secretion.	Urogastrone(?).
37 Gastrin	IEP=8; heat stable; destroyed by UV, alk., pepsin; dialyzable.	Gastric mucosa, especially pylorus.	No standard assay method.	
38 Pancreozymin	Salted out by NaCl; s. absolute al., w.	Upper intestinal mucosa.	Increase in enzymes in pancreatic juice.	Unknown.
39 Secretin	MP=234; salted out by NaCl, CCl ₃ COOH; s. dilute acidic w.		Volume of pancreatic juice (dog).	
40 Urogastrone	Similar to enterogastrone; not destroyed by pepsin. ⁷	Urine.	≈ enterogastrone.	
Neuro				
41 Acetylcholine; ACh; [Br] Pragnoline; [Cl] Acecoline	MW=163; MP (Br)=143; quart. salt unstable; s. w., al., eth., oils; salts v. s. w.; i. eth.	Ganglia of parasymp. nervous system; brain; synth. commercially.	None.	

/1/ ac. = acid; acet. = acetone; al. = alcohol (ethanol, 95%); alk. = alkali; aq. = aqueous; bz. = benzene; chl. = chloroform; diox. = dioxane; eth. = ether; HCG = human chorionic gonadotropic; i. = insoluble; IEP = isoelectric point; me. al. = methyl alcohol; MP = Melting Point; MW = molecular weight; org. = organic; PMS = pregnant mare serum; pptd. = precipitated; s. = soluble; sl. = slightly; sol. = solution; solv. = solvents; synth. = synthesized; v. = very; vol. = volatile; w. = water; wt. = weight; -x = -ectomized (e.g., hypo-x = hypophysectomized). /4/ Evidence for 2 fractions of TSH: (1) stimulation hypertrophy of acinar cells and colloid secretion from gland; (2) acceleration I⁻ uptake from blood, hormone synthesis. /5/ Circulating hormone probably thyroxine protein. Thyroglobulin (MW 650,000 and IEP 5) isolated from gland; circulating hormone may be 1/4 of this. Triiodothyronine is probably the tissue active compound; it is 5-7 times as potent as thyroxine. /6/ A polymer of 6 units of MW about 6000. /7/ Only the motor-inhibitory effect.

334. VERTEBRATE HORMONES: PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS (Continued)

Part II: BIOLOGICAL PROPERTIES

Numbers in brackets refer to hormones listed in Part I.

† = decreased; ‡ = increased; (S) = stimulated; PMS = pregnant mare serum.

Hormone Number	Targets	Principal Effects	Effect of Deficiency (-) Excess (+)	Secretion Inhibited by (I) Stimulated by (S)
Adrenal Cortex				
1 [1]	See [3, 4]; chiefly kidneys, interstitial fluid; (mineralo-corticoid).	Promotes renal excretion of K, and retention of Na and Cl; 25-100 times more potent than [2]. Some properties of glucocorticoids (q.v.).	- Hemoconcentration; † Na, H ₂ O (blood, muscle); † K retention. + Reverse of above; hypertension; congestive heart failure.	(S) low blood Na (?).
2 [2]	Same as [1]. (mineralo-corticoid).	Similar to [1].	Similar to [1], but effects much less pronounced.	
3 [3]	Muscles, liver, capillaries, kidneys, pancreas (?), integument, lymphoid organs and bone marrow, circulating blood cells; (gluco-corticoid).	Effects of gluco-corticoids [3, 4, 5, 6] are qualitatively comparable but differ quantitatively as follows: for glycogen deposition in liver, muscle work performance, hypersensitivity reactions, and thymus involution, the relative potencies are [5] = 1.5, [6] = 1.0, [3] = 0.5, [4] = 0.5; gluconeogenesis, [5] > [4] = [3]; maintenance of renal function, [1] > [2] > [4] = [3] > [5] = [6]; K/Na ratio and H ₂ O balance, [1] > [2] > [4] = [3]; recovery muscular fatigue, [2] > [3] > [5] > [6]; cold protection, [6] > [4] > [3] > [2]; CHO metabolism, [5] > [3] > [2]; collagen maintenance, [6]; anti-inflammatory, [5, 6, 9]; normal capillary permeability, [5, 6, 4]; protection against stress, [4, 5, 6]; protection against shock, [2].	- Asthenia; hemoconcentration; skin pigmentation; † weight; blood glucose, liver glycogen, stress resistance, blood pressure; † K/Na ratio in serum. + Reverse of above; Cushing's syndrome; hirsutism.	(S) ACTH.
4 [4]	See [3, 4]; particularly muscle, liver, connective tissue; (gluco-corticoid).			
5 [5]	Synthetic. More potent than [5, 6] in rheumatoid arthritis.			
6 [6]				
7 [7]				
Ovaries				
8 [8]				
9 [9]				
10 [10]	All female sex organs; mammary glands; mucous membranes; anterior pituitary.	Estrogenic. Endometrial proliferation; development and maintenance of vaginal mucosa, cornification of superficial layer; antagonizes androgen effects; † development mammary gland ducts, uterine motility, growth axillary and pubic hair (♀ human), growth of down (♀ bird), growth all ♀ secondary sex organs, estrus. Potency [10] > [12] > [11].	- † development accessory sex organs, mammary glands, secondary sex characteristics, and ♀ behavior pattern. + Precocious maturity; hypertrophy accessory sex organs and mammary glands; precocious epiphyseal maturation and closure; estrus changes; cystic hyperplasia of endometrium.	(S) LH; FSH + LH (?).
11 [11]				
12 [12]				
13 [13]	Uterus; mammary glands.	Luteinizing. Preparation of endometrium for implantation of zygote; † uterine contractions; † development mammary glands, metabolism and excretion of estrogens.	- † uterine motility and bleeding; abortion. + Prolongation of cycle; dysmenorrhea (?); † Na, H ₂ O retention.	(S) LTH (?).
14 [14]	Pelvic ligaments.	Relaxation pelvic ligaments.	(?)	(S) estrogens (?).
Placenta				
15 [15]	Ovaries (pregnancy, man and horse).	Maintenance corpus luteum in pregnancy; HCG → luteinizing corpus luteum; PMS → luteinization, follicle development.	- Abortion. + Toxemias of pregnancy (?).	(I) sex steroids.
Testes (and Androgens from Urine)				
16 [16]				
17 [17]	All male sex organs; anterior pituitary; muscle.	Androgenic. † development ♂ secondary sex organs and sex characteristics, BMR, protein anabolism, retention Na and K, folliculoid and luteoid activity (♀ immature); † creatinuria.	- † development ♂ sex organs and sex characteristics, excretion 17-ketosteroids in urine. + Precocious sex development; rapid body growth; † scalp hair (?); † hirsutism; † excretion 17-ketosteroids.	(I) sex steroids.
18 [18]				
19 [19]	Seminiferous tubules.	† spermatogenesis even in hypophysectomized or folliculoid-overdosed animals.	(?)	
Anterior Pituitary				
20 [20]	Adrenal cortex.	† lipid and ascorbic acid content of adrenal cortex; † secretion adrenal cortical hormones.	- Atrophy and hypofunction of adrenal cortex; † response to stress. + Hyperfunction adrenal cortex.	(I) circulating adrenal cortex hormones. (S) stress; epinephrine(?).
21 [21]	Ovarian follicles; seminiferous tubules.	† spermatogenesis and growth seminiferous tubules, development follicles (not ova production or estrogen secretion unless ICSH present).	- Obesity; † H ₂ O metabolism, ovarian dysfunction. + No syndrome associated with FSH alone.	(I) circulating androgens and/or estrogens. (S) castration; low blood level of androgens and/or estrogens.
22 [22]	Bones, especially epiphyseal cartilage; most tissues.	† skeletal and soft-tissue growth, protein anabolism; † pancreatic insulin († in rat), maintenance muscle growth.	- Dwarfism and/or infantilism; delayed closure apiphyses. + Gigantism and/or acromegaly; hypertrophy of viscera ¹ .	(I) estrogens or androgens (large doses).
23 [23]	Maturing Graafian follicles and interstitial cells (ovaries); interstitial cells of Leydig (testes).	† follicle maturation (production but not maintenance corpus luteum), secretion estrogens, and androgens from testes.	- † ovulation; atrophy of Leydig cells. + Secretion estrogens and androgens; precocious development or ovulation.	(S) high blood level of ovarian and testicular hormones.
24 [24]	Mammary glands; crop-sac (pigeon); ovarian corpus luteum.	† milk secretion, progesterone secretion by developed corpus luteum, uterine nidation and decidua, growth and secretion of crop gland (pigeon).	- † milk secretion, progesterone. + † milk secretion.	(I) or (S) by effects of androgens, FSH; ICSH, and progesterone on target organs.
25 [25]	Thyroid gland	† synthesis and secretion of thyroid hormone, cell height of thyroid epithelium, thyroid size, serum protein bound iodine; † iodine and colloid content of thyroid.	- Myxedema; cretinism (some forms); † BMR. + Goiter; hyperthyroidism; † BMR; exophthalmos ² .	(I) † circulating TH; (I) or (S) by nervous system. (S) † circulating TH.

/1/ More characteristic of acromegaly, since long bones do not lengthen. /2/ May be caused by "exophthalmos factor" that can be separated from TSH.

334. VERTEBRATE HORMONES: PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS (Concluded)

Part II: BIOLOGICAL PROPERTIES (Concluded)

Numbers in brackets refer to hormones listed in Part I.

↓ = decreased; ↑ = increased; (S) = stimulated.

Hormone Number	Targets	Principal Effects	Effect of Deficiency (-) Excess (+)	Secretion Inhibited by (I) Stimulated by (S)
Pituitary Intermediate Lobe				
26 [26]	Chromatophore cells in skin of lower vertebrates	Expands chromatophores → pigment granules to disperse and color skin.	- Contraction chromatophores; ↓ skin pigment. + ↑ skin pigmentation, melanin synthesis; hyperglycemia.	(S) central nervous system; ACTH (chromatophore expansion).
Posterior Pituitary				
27 [27]	Uterine and other smooth muscles; mammary glands	Stimulates contraction uterine muscle, (and other smooth muscles too lesser degree), milk secretion.	- Delayed uterine contraction (pre- or postpartum); ↓ milk flow. + ↑ milk flow; abortion (?).	(S) suckling (?).
28 [28]	Capillaries; arterioles; coronary vessels; kidney vascular bed and tubules	↑ kidney excretion of H ₂ O ³ ; ↓ excretion of NaCl and urea, ↑ blood pressure (constriction of capillaries).	- Diabetes insipidus ³ ; ↓ excretion NaCl and urea. + ↑ H ₂ O retention.	(S) ↓ plasma osmotic conc. (I) ↓ plasma osmotic conc.
Parathyroid				
29 [29]	Bones; kidneys	Controls Ca and PO ₄ level in blood via mineral exchange between blood and bones, and PO ₄ excreted by kidneys.	- Tetany; convulsions; coma; death; ↓ Ca, ↑ PO ₄ (serum); muscle spasm; cataract, scaly skin, hair loss (?). + ↑ PO ₄ , ↑ Ca (serum); ↑ alkaline phosphatase, excretion PO ₄ ; decalcification bones; renal calcification.	(S) low Ca, high PO ₄ diet; ↑ serum PO ₄ , ↑ serum Ca (?).
Thyroid				
30 [30]	All body cells	↑ oxidations; regulation of rate of CHO, fat, protein, H ₂ O, mineral metabolism; stimulates growth, maturation, neuromuscular function, skin development, hematopoiesis, spermatogenesis and oogenesis, lactation; regulation of TSH secretion.	- Myxedema; cretinism (some types in fetus, child); retardation of ossification and epiphyseal maturation. + Hyperthyroidism; Grave's disease; exophthalmos. ²	(I) anti-thyroid drugs. (S) TSH.
Pancreas				
31 [31]	Skeletal muscle; probably adipose tissue	Regulation CHO metabolism; ↑ oxidation tissue glucose (hexokinase) (?); ↑ gluconeogenesis, ↑ ketogenesis (indirect) (?).	- Diabetes mellitus (hyperglycemia, glycosuria, ketonuria; ↓ weight and blood volume; - nitrogen balance); delayed wound healing; gangrene. + Hyperinsulinism (hypoglycemia, convulsions, nausea, muscular weakness, anxiety and confusion).	(I) Pituitary extracts; GH; in tissues by epinephrine, glucocorticoids. (S) ↑ blood glucose; vagus stimulation.
Adrenal Medulla				
32 [32]	Sympathetic nervous system; heart muscle; smooth and skeletal muscles; liver	↑ contraction heart muscle (↑ output and rate), spleen, gravid uterus, iris muscle (radial), capillaries; relaxation non-gravid uterus, peripheral arterioles, bronchial muscles; ↑ peristalsis; ↓ glucogenolysis, BMR, blood coagulation; stimulates secretion ACTH (?), salivary, sweat glands.	- No clinical syndrome. + Over-secretion rare; may cause paroxysmic hypertension, and, in some instances, sustained hypertension.	(S) sympathetic nervous system, via splanchnic nerve; "stress."
33 [33]	See [32]	Similar to [32], but causes arteriole constriction, hyperglycemia; no effect on cardiac output; pressor effect is not reversed by ergotoxine (as is that of [32]).		
Gastrointestinal Tract				
34 [34]	Gallbladder	Stimulates contraction and emptying of gallbladder.		(S) fat, protein, acid in duodenum.
35 [35]	Secretory cells of ileum, jejunum	↑ secretion succus entericus, volume rate and enzyme concentration.		(S) food in intestine.
36 [36]	Stomach	↑ motor activity and acid secretion of stomach.	(?)	(S) sugar, fat in intestine.
37 [37]	Parietal (HCl-producing) cells, stomach	↑ HCl secretion (but not pepsin) by gastric mucosa.		(S) mechanical distention; protein degradation products.
38 [38]	Enzyme-secreting cells of pancreas	↑ enzyme secretion by pancreas; no effect on volume rate.		(S) Peptones, amino acids, soaps, fats in duodenum.
39 [39]	Pancreas (acinar or exocrine), liver	↑ volume rate of pancreatic enzymes; no effect on concentration; stimulates bile secretion.	- Hyposecretion pancreatic enzymes and bile. + Excess doubtful.	(S) HCl, protein degradation products, digested fat or bile in small intestine.
40 [40]	Gastric mucosa and muscularis	↑ HCl secretion, muscular contractions stomach.	(?)	
Neuro				
41 [41]	Muscles, especially involuntary (ACh released at neuromuscular junctions, synapses)	Conduction electrical impulses along nerve fibers; ↑ heart rate; dilatation arterioles; effects (cholinergic) generally opposite to those of epinephrine (adrenergic).	(?)	

/2/ May be caused by "exophthalmos factor" that can be separated from TSH. /3/ Antidiuretic hormone (ADH) fraction.

335. ANTIHISTAMINICS: PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS

Generic Name [Trade Name]	Structural Formula	Molecular Formula [Molecular Weight]	Solubility ¹	Mouse LD ₅₀ mg/kg	Bena- dryl Ratio ²	Anes- thesia min ³	Atropine Ratio ⁴	Epineph- rine Po- tentiation ⁵	Side Effects ⁶
1 Diphen- hydramine HCl [Benadryl]		C ₁₇ H ₂₁ NO·HCl [291.81]	s.w., al., chl.; sl.s. bz., eth.	31 (IV) 83 (IP) 206 (PO) 129 (SC)	1.0 (a, b, c, d, e)	22	0.02	Yes	Sedation, dizziness, dry mouth, lassitude, excitement, nausea.
2 Antazoline HCl [Antistine]		C ₁₇ H ₁₉ N ₃ ·HCl [301.82]	s.al.;sl.s. w.;i.bz., eth.	39 (IV- rats) 150 (IP)	0.1 (a) 0.5 (b)	20	<0.001	No	Dry mouth, head- ache, tachycardia, nervousness, nausea.
3 Bromo- diphen- hydramine HCl [Ambodryl]		C ₁₇ H ₂₀ BrNO ·HCl [370.73]	s.w.	108 (IP)	1.4 (a) 2.2 (b)		0.005	Yes	Dizziness, anorexia, dry mouth, diarrhea.
4 Carbinox- amine maleate [Clistin]		C ₁₆ H ₁₉ ClN ₂ O ·C ₄ H ₄ O ₄ [406.86]	s.w., al., chl.;sl.s. eth.	411 (PO)	24.0 (e)	0	Weak	No	Somnolence, dizziness, dry mouth, gastric pain.
5 Chlor- cyclizine HCl [Perazil]		C ₁₈ H ₂₁ ClN ₂ ·2HCl [373.57]	s.w., chl., al.;i.bz., eth.	137 (IP)	1.0 (a) 7.0 (b) 4.0 (d)	22	Moderate	Yes	Dry mouth, head- ache, blurred vision, insomnia, palpitation, gastric disturbances.
6 Chlorothen citrate [Chlorothen; tagathen]		C ₁₄ H ₁₈ ClN ₃ S ·C ₆ H ₈ O ₇ [487.95]	s.w.;sl.s. al., eth.	26 (IV) 105 (IP)	10.0 (a)		0.01		Sedation, dizziness, headache, gastric disturbances.
7 Chlor- phenir- amine maleate [Chlor- trimeton]		C ₁₆ H ₁₉ ClN ₂ ·C ₄ H ₄ O ₄ [390.86]	s.w., al., chl.;sl.s. bz., eth.	40 (IV) 77 (IP) 176 (PO) 104 (SC)	3.0 (a) 29.0 (b) 35.0 (e)	15	0.001	Yes	Jitteriness, dry mouth, gastric disturbances.
8 Doxylamine succinate [Decapryn]		C ₁₇ H ₂₂ N ₂ O ·C ₄ H ₆ O ₄ [388.45]	s.w., al., chl.;sl.s. bz.	62 (IV) 470 (PO) 460 (SC)	1.0 (a) 2.5 (e)	16	<0.001		Sedation, dizziness, headache, derma- titis, gastric dis- turbances.
9 Meta- phenylene HCl [Diatrin]		C ₁₅ H ₂₀ N ₂ S ·HCl [296.86]	s.w.;sl.s. al., chl.; i.eth.	117 (IP)	1.7 (a) 1.3 (b)		0.007		Irritability, burn- ing of the skin, gastric dis- turbances.
10 Metha- pyrilene (Thenyl- pyramine) HCl [Thenylene; Histady]		C ₁₄ H ₁₉ N ₃ S ·HCl [297.85]	s.w., al.; i.bz., eth.	20 (IV) 77 (IP) 182 (PO)	5.0 (a) 4.0 (b)	17	0.002	Yes	Dizziness, dry mouth, headache, nervousness, nausea.

/1/ Abbreviations: al. = alcohol (ethanol 95%); bz. = benzene; chl. = chloroform; eth. = ether; glyc. = glycerol; i. = insoluble; s. = soluble; sl. = slightly; w. = water. /2/ Benadryl Ratio as based on: (a) isolated guinea pig ileum; (b) bronchoconstrictor effect of histamine aerosol in guinea pigs; (c) vasodepressor response to histamine in dogs; (d) guinea pig tracheal chain; (e) bronchoconstrictor effect of intravenous histamine in guinea pigs. /3/ Corneal local anesthesia duration in rabbits or guinea pigs, using 1% solution. /4/ Anticholinergic effect on isolated rabbit intestine. /5/ Potentiation of epinephrine pressor effect. /6/ In addition to drowsiness, which is a side effect common to all drugs listed.

335. ANTIHISTAMINICS: PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS (Concluded)

Generic Name [Trade Name]	Structural Formula	Molecular Formula [Molecular Weight]	Solubility ¹	Mouse LD ₅₀ mg/kg	Bena- dryl Ratio ²	Anes- thesia min ³	Atropine Ratio ⁴	Epineph- rine Po- tiation ⁵	Side Effects ⁶
12 Phenir- damine tartrate [Thephorin]		C ₁₉ H ₁₉ N ·C ₄ H ₆ O ₆ [297.82]	s.w.; sl. s. propylene glycol; i. al., glyc., eth.	23 (IV) 88 (IP) 280 (PO) 300 (SC)	2.0 (b) 9.3 (d)		0.003	No	Dizziness, head- ache, anorexia, palpitations, rest- lessness, depres- sion, nausea.
13 Phenir- amine maleate [Trimeton]		C ₁₆ H ₂₀ N ₂ ·C ₄ H ₄ O ₄ [356.41]	s.w., al.; sl. s. bz., eth.	60 (IV) 65 (IP) 225 (PO) 132 (SC)	2.0 (b) 1.3 (d) 2.0 (e)	0	<0.001	Yes	Dry mouth, weak- ness, gastric dis- turbances.
14 Phenyl- tolox- amine HCl [Bristamin]		C ₁₇ H ₂₁ NO ·HCl [291.82]	s.w.	33 (IV) 163 (IP) 424 (PO)	1.1 (b)	Same as procaine q. v.	0.01	No	Dry mouth.
15 Prometh- azine HCl [Phenergan]		C ₁₇ H ₂₀ N ₂ S ·HCl [320.88]	s.w., al., chl.	55 (IV) 200 (PO) 190 (IP)	2.5 (a) 4-10 (b)	69	Moderate	Yes	Dizziness, weak- ness, dry mouth, nausea, vomiting.
16 Pyra- thiazine HCl [Pyrrolazote]		C ₁₈ H ₂₀ N ₂ S ·HCl [332.89]	s.w., al.	37 (IV) 445 (PO) 1340 (SC)	4.0 (a) 4.0 (b)	53	0.004	No	Headache, nausea.
17 Pyrilamine maleate [Neo- antergan]		C ₁₇ H ₂₃ N ₃ O ·C ₄ H ₄ O ₄ [401.45]	s.w., al.; sl. s. bz., eth.	30 (IV) 102 (IP) 150 (SC)	10.4 (a) 28.0 (b) 1.0 (c) 17.1 (d)	21	0.002	Yes	Vertigo, dry mouth, nervous- ness, headache, nausea.
18 Pyrro- butamine phosphate [Pyronil]		C ₂₀ H ₂₂ ClN ·2H ₃ PO ₄ [507.86]	s.h.w.	54 (IV) 1116 (PO) 1270 (SC)	14.0 (a) 20.0 (b)	92	Weak		Dizziness, dry mouth, headache, palpitation, nervousness, nausea, diarrhea.
19 Thenyl- diamine HCl [Thenfadi]		C ₁₄ H ₁₆ N ₃ S ·HCl [297.85]	s.w.; sl. s. al.	14 (IV) 55 (IP) 277 (PO) 36 (SC)	1.0 (c)		0.0025		
20 Thonzyl- amine HCl [Neohetramine]		C ₁₆ H ₂₂ N ₄ O ·HCl [322.83]	s.w., al., chl.; i. eth.	119 (IP) 245 (PO)	1.0 (b) 4.0 (d)	Same as procaine q. v.	Weak	No	Dry mouth, headache, nervousness, nausea.
21 Tripel- ennamine HCl [Pyri- benzamine]		C ₁₆ H ₂₁ N ₃ ·HCl [291.82]	s.w., al., chl.; i. bz., eth.	16 (IV) 74 (IP) 210 (PO) 71 (SC)	5.0 (a) 6.5 (b) 5.0 (c) 1.0 (e)	17	0.0025	Yes	Dizziness, dry mouth, headache, excitement, gastric disturbances.

/1/ Abbreviations: al. = alcohol (ethanol 95%); bz. = benzene; chl. = chloroform; eth. = ether; glyc. = glycerol; i. = insoluble; s. = soluble; sl. = slightly; w. = water. /2/ Benadryl Ratio as based on: (a) isolated guinea pig ileum; (b) bronchoconstrictor effect of histamine aerosol in guinea pigs; (c) vasodepressor response to histamine in dogs; (d) guinea pig tracheal chain; (e) bronchoconstrictor effect of intravenous histamine in guinea pigs. /3/ Corneal local anesthesia duration in rabbits or guinea pigs, using 1% solution. /4/ Anticholinergic effect on isolated rabbit intestine. /5/ Potentiation of epinephrine pressor effect. /6/ In addition to drowsiness, which is a side effect common to all drugs listed.

336. THERAPEUTIC AGENTS: EFFECTIVE BLOOD LEVELS

Blood levels and dosages indicated in this table are not to be interpreted as recommendations of the National Academy of Sciences - National Research Council, nor does the appearance of a trade name imply such endorsement for the product or its manufacturer. These are presented for informative purposes only.

Therapeutic Agent	Common or Trade Name	Use	Dosage	Route of Administration ¹	Minutes After Administration ²	Blood Concentration ³ mg/100 ml ²
Antibiotics						
1 Chloramphenicol	Chloromycetin	Infections caused by G+ and G- bacteria, viruses.	0.5 g	O	30	0.4 (P)
2 Chlorotetracycline HCl	Aureomycin HCl	Broad spectrum antibiotic.	250 mg	O	120-240	0.1-0.3 mg (P)
3 Erythromycin		Infections caused by G+ bacteria.	300 mg	O	60-120	0.015 mg
4 Oxytetracycline	Terramycin	Broad spectrum antibiotic.	250 mg	O	120-240	0.1-0.3 mg (P)
5 Penicillin G procaine		Infections caused by G+ bacteria.	300,000 units	IM	60-180	0.06 mg (S)
6 Tetracycline	Achromycin	Broad spectrum antibiotic.	250 mg	O	120-240	0.1-0.3 mg (P)
Antihistaminics						
7 Diphenhydramine HCl	Benadryl HCl	Histamine antagonist.	50 mg	O	15-30	
8 Tripeleminamine HCl	Pyribenzamine HCl	Histamine antagonist.	50 mg	O	15-30	<300 µg (P)
Antimalarial Drugs						
9 Chloroquine di-PO ₄	Aralen-SN 7618	Suppressive, therapeutic.	1 g (start); 500 mg (6 hr); 500 mg (2nd, 3rd da) ⁴	O	Slow	0.015-0.020 mg (P)
10 Pyrimethamine	Daraprim	Suppressive antimalarial.	100 mg ⁵	O	60-120	0.08-0.16
11 Quinacrine HCl	Atabrine	Suppressive, therapeutic.	200 mg (every 6 hr for 5 doses); then 100 mg (3 times daily for 6 da) ⁴	O	Slow	0.002-0.003 mg (S)
Antituberculosis Drugs						
12 Isoniazid		Tuberculosis therapy.	100 mg	O	120-180	0.13-0.34 (P)
13 Para-amino-salicylic acid	PAS	Tuberculosis therapy.	4 g	O	30-60	10
14 Streptomycin SO ₄		Tuberculosis therapy; infections caused by G- bacteria.	500 mg	IM	30-180	0.7-1.5 (P)
Autonomic Nervous System Drugs						
15 Atropine SO ₄		Parasympatholytic.	0.5 mg	O	15	
16 Bethanechol Cl	Urecholine	Parasympathomimetic.	20 mg	O	30	
17 Ephedrine SO ₄		Sympathomimetic.	25 mg	O, SC	20	
18 Epinephrine HCl	Adrenalin	Sympathomimetic.	0.5 mg	SC	5	
19 Neostigmine Br		Parasympathomimetic.	2 mg	IM	5	
20 Priscoline	Prostigmine Br	Sympatholytic.	15 mg	O	15	9x10 ⁻³ (P)
			25 mg	O	15	<1
Cardiovascular Drugs						
21 Aminophylline		Angina pectoris, coronary thrombosis, asthma.	200 mg	O	30-60	0.3-0.4 as theophylline
22 Digitoxin		Cardiac decompensation.	0.1 mg	O	30-120	<1 µg
23 Glyceryl trinitrate	Trinitroglycerine	Angina pectoris.	0.4 mg	SL	2-5	
24 Quinidine SO ₄		Auricular fibrillation.	200 mg	O	60-120	0.2-0.4 mg
Central Nervous System Depressants						
Analgesics, hypnotics, and sedatives						
25 Acetophenetidine	Phenacetin	Analgesia.	300 mg	O	15-30	>0.1 (P)
26 Acetylsalicylic acid	Aspirin	Analgesia.	600 mg	O	15-30	2-3 (P)
27 Amobarbital sodium	Amytal sodium	Hypnosis.	100 mg	O	30	0.6-0.8
28 Codeine phosphate		Analgesia.	30 mg	O	30	
29 Meperidine HCl	Demerol	Analgesia.	100 mg	IM	15-30	0.125 (P)
30 Methadone	Amidone; Dolophine	Analgesia.	7.5 mg	O or SC	15-30	
31 Morphine SO ₄		Analgesia.	15 mg	O or SC	15-30	250 µg
32 Paraldehyde		Analgesia ⁶ .	4 (1-30) g ⁷	R or O	30	11.8-24.4 (S)
33 Pentobarbital sodium	Nembutal sodium	Hypnosis.	100 mg	O	15	0.2-0.3
34 Phenobarbital sodium	Luminal sodium	Sedation.	30 mg	O	30	5
35 Secobarbital sodium	Seconal sodium	Hypnosis.	100 mg	O	15	0.2-0.3
36 Sodium bromide		Sedation.	1 g	O	60	16-50
Anesthetics						
37 Chloroform		Surgical anesthesia.	1.5 vol %	I	5	15-20
38 Cyclopropane		Surgical anesthesia.	20-30 vol %	I	2-3	15
39 Ether, ethyl		Surgical anesthesia.	6-10 vol %	I	15-20	50-130
40 Ether, ethyl vinyl	Vinamar	Surgical anesthesia.	6 vol %	I	2-4	50
41 Ether, methyl-n-propyl	Neothyl	Surgical anesthesia.	2.5-3 vol %	I	10-15	30-60
42 Ether, vinyl	Vinethene	Surgical anesthesia.	4 vol %	I	1-2	28
43 Ethyl alcohol		Euphoria.	30 ml	O	15-30	30
44		Hypnotic.	100 ml	O	15-30	100
45		Anesthesia (stupor).	300-400 ml	O	15-30	300-400
46 Ethyl chloride		Surgical anesthesia.	3-4.5 vol %	I	2	20-30
47 Ethylene		Anesthesia (Plane 1).	80-85 vol %	I	20	120-180
48 Nitrous oxide		Anesthesia (Plane 1).	85-92 vol %	I	2	23 vol %
49 Thiamylal sodium	Surital sodium	Short surgical procedures.	3-6 ml of 2.5% solution ⁸	IV	1-10	1.5-2
50 Thiopental sodium	Pentothal sodium	Short surgical procedures.	2-3 ml of 2.5% solution ⁹	IV	1-10	1.5-2
51 Tribromethanol (soln)	Avertin	Basal anesthesia.	80-100 mg/kg	R	30	6-9
Anticonvulsants						
52 Diphenylhydantoin sodium	Dilantin	Anti-epileptic.	100 mg ¹⁰	O	2-3 da	3-6
53 Trimethadione	Tridione	Anti-epileptic.	300 mg ¹¹	O	2-3 da	4-6 (P)
Central Nervous System Stimulants						
54 Caffeine		Central stimulant.	200 mg	O	15-30	0.1-0.2 (P)
55 Dextroamphetamine SO ₄	Dexedrine	Central stimulant.	5 mg	O	30	Not available
Pentylenetetrazol	Metrazol	Respiratory stimulant.	100 mg	IV, SC	5-15	Not available

/1/ Inhalation; IM=intramuscular; IV=intravenous; N=nasal; O=oral; PA=parenteral; R=rectal; SC=subcutaneous; SL=sublingual. /2/ Unless otherwise indicated. /3/ (P)=plasma; (S)=serum. /4/ Therapeutic dose. /5/ Usual dose, 25 mg. /6/ Also as anti-convulsant and in alcoholic psychoses. /7/ Range, depending upon use. /8/ At rate of 1 ml per 5 sec. /9/ In 15 sec; repeat in 30 sec as required. /10/ 2-4 times per day. /11/ 3-6 times per day.

336. THERAPEUTIC AGENTS: EFFECTIVE BLOOD LEVELS (Concluded)

Blood levels and dosages indicated in this table are not to be interpreted as recommendations of the National Academy of Sciences - National Research Council, nor does the appearance of a trade name imply such endorsement for the product or its manufacturer. These are presented for informative purposes only.

Therapeutic Agent	Common or Trade Name	Use	Dosage	Route of Administration ¹	Minutes After Administration ²	Blood Concentration ³ mg/100 ml ²
Diuretics						
57	Acetazoleamide	Diuretic.	250 mg	O	60-120	
58	Meralluride	Diuretic.	1 ml ¹²	PA	180	Not available
59	Mercaptopimerin sodium	Diuretic.	130 mg (in 1 ml)	PA	180	Not available
Hematopoietic Drugs						
60	Ferrous sulfate	Secondary anemia.	300 mg	O	Variable	105 µg as Fe (P)
61	Vitamin B ₁₂	Pernicious anemia.	15 µg	IM	60	
Hormones						
62	Corticotropin	Adrenocorticotrophic hormone.	10 U.S.P. Units ¹³	IV	Slow	
63	Cortisone acetate	Collagen diseases.	25 mg ¹⁴	O	Slow	
64	Diethylstilbestrol	As estrogen.	0.5 mg	O	Slow	
65	Hydrocortisone acetate	Collagen diseases.	10 mg ¹⁰	O	Slow	
66	Insulin(s)	Diabetes.	No official dose	SC	60-360 ¹⁵	
67	Methyltestosterone	As androgen.	10 mg	O or SL	Slow	
68	Thyroxine	Mild hypothyroidism.				
Sulfonamides						
69	Sulfadiazine	Antibacterial.	4 g ¹⁶	O	180-240	8, free form
70	Sulfamerazine	Antibacterial.	4 g ¹⁶	O	180-240	9.8, free form
71	Sulfamethazine	Antibacterial.	4 g ¹⁶	O	180-240	7.8, free form
72	Sulfasoxazole	Antibacterial.	4 g ¹⁶	O	180-240	6-8, free form
Vitamins						
73	Ascorbic acid	Vitamin deficiency.	75 mg ¹⁷ ; 150 mg ¹⁸	O	Readily	1-2(P)
74	Nicotinic acid	Vitamin deficiency.	100 mg	O	Slow	
75	Riboflavin	Vitamin deficiency.	3 mg ¹⁷ ; 5 mg ¹⁸	O	Readily	
76	Thiamine HCl	Vitamin deficiency.	25 mg	O	Readily	
77	Vitamin A	Vitamin deficiency.	25,000 Units ¹⁸ (adult)	O	Slow	0.03 mg; vitamin A alcohol
78	Vitamin D, oleo-(synthetic)	Vitamin deficiency.	50,000 U.S.P. Units	O	Slow	5x10 ⁻⁴
Miscellaneous						
79	Carbarsonne	Amebic dysentery.	250 mg	O		

/1/ I=inhilation; IM=intramuscular; IV=intravenous; N=nasal; O=oral; PA = parenteral; R=rectal; SC=subcutaneous; SL=sublingual. /2/ Unless otherwise indicated. /3/ (P)=plasma; (S)=serum. /10/ 2-4 times per day. /12/ Equivalent to 39 mg Hg and 45 mg theophylline. /13/ In 8 hr infusion. /14/ Four times daily. /15/ Dependent on type. /16/ Initial dose. /17/ Requirement. /18/ Therapeutic dose.

337. BARBITURATES: PLASMA LEVELS AT AWAKENING

With each dosage administered, objective was to produce sleep. Plasma concentrations were determined at time of awakening. For many investigations this is the critical dose level, inasmuch as any significantly greater concentration would be a hypnotic or anesthetic level. Ranges, in parentheses, conform to estimate "b" of the 95% range (cf Introduction).

Barbiturate					Animal	Dosage mg/kg ¹	Route of Admin- istration ²	Plasma ¹ Concentration mg/100 ml	Barbiturate					Animal	Dosage mg/kg ¹	Route of Admin- istration ²	Plasma ¹ Concentration mg/100 ml
1	Barbital	Man	200	O	1.5 ³	23	Thiamylal	Dog	21	IV	0.95(0.83-1.07)						
2		Man	600 ⁴	O	0.8 ³	24	Thioethamyl	Dog	20	IV	2.3(0.7-3.9)						
3	Hexobarbital	Rat	100	IP	4.1	25	Thiopental	Man	22	IV	1.3						
4	5-Isopropyl-5-(2-methylpentyl)-2-thio-barbiturate, sodium	Dog	21	IV	0.64(0.38-0.90)	26		Man	33	IV	1.7						
5	Pentobarbital	Man	800 ⁴	O	0.8 ³	27		Man	36	IV	2.3						
6		Man	2000 ⁴	O	1.0 ³	28		Man	40	IV	1.9						
7		Man	750-1000 ⁴	IV	0.8 ³	29		Man	43	IV	2.0						
8		Dog	20	IV	1.5(1.1-1.9)	30		Man	50	IV	2.6						
9		Dog	25	IV	1.7(1.3-2.1)	31		Man	54	IV	2.5						
10		Mouse	50	IP(?)	2.6	32		Man	59	IV	3.3						
11		Rabbit	15	IV	1.0(0.8-1.2)	33		Man	65	IV	2.7						
12		Rabbit	25	IV	1.0(0.6-1.4)	34		Man	67	IV	2.8						
13		Rabbit	30	IV	1.2(0.8-1.6)	35		Dog	10	IV	0.9 ⁵						
14		Rabbit	35	IP	1.2(0.4-2.0)	36		Dog	20	IV	1.2(1.1-1.3)						
15		Rat	30	IP	2.9	37		Dog	25	IV	1.7 ⁶						
16		Rat	60	IP	2.0	38		Dog	30	IV	1.5 ⁵						
17	Phenobarbital	Man	(?)	O	1.2	39		Dog	35	IV	1.8 ⁵						
18	Secobarbital	Man	600	O	0.8	40		Dog	40	IV	2.4 ⁶						
19		Dog	20	IV	1.1(0.9-1.3)	41		Mouse	30	IV	3.2 ⁶						
20		Dog	25	IV	1.2(1.0-1.4)	42		Mouse	45	IV	4.9 ⁶						
21		Rabbit	15	IV	1.0(0.8-1.2)	43		Mouse	70	IP	2.7(2.3-3.1)						
22		Rabbit	25	IV	0.8(0.4-1.2)	44		Mouse	70	IV	2.2 ⁵						
						45		Rabbit	25	IV	2.3(1.7-2.9)						
						46		Rabbit	27	IV	1.9(1.1-2.7)						

/1/ Unless otherwise indicated. /2/ O = oral; IP = intraperitoneal; IV = intravenous. /3/ Approximate. /4/ Mg per individual. /5/ Estimated from graph. /6/ Serum.

338. SOME ORGANIC COMPOUNDS AFFECTING CELL DIVISION

Data in this table are only a representative sample of the voluminous literature on the subject.

Part I: EFFECTS ON MITOSIS AND MEIOSIS

Compound		Organism, Part Affected	Effect	Compound		Organism, Part Affected	Effect
Interphase				Anaphase			
1 Auxin		Cambium	Division stimulated.	42 Caffeine		Onion root	Incomplete chromo- some separation.
2 Glucose		Mouse epidermis		43 Ryanodine		Sea urchin egg	
3 Hypoxanthine		Chick osteoblasts		44 Trypaflavine		Rabbit fibroblast	
4 Indoleacetic acid		Onion root		Telophase			
5 Acridines		Chick fibroblasts	Initiation of prophase inhibited.	45 Aureomycin		Chick fibroblasts	Cytoplasmic division suppressed.
6 Azaguanine		Mouse tumors		46 Caffeine		Onion root	
7 Dyes		Frog sperm		47 Carbamates		Sea urchin egg	
8 Nitrogen mustard		Animals		48 Nicotine		Tobacco anthers	
9 Phenylacetic acid		Onion root	49 Quinone		Worm egg		
10 Cortisone		Onion root	50 Rotenone		Sea urchin egg		
11 Naphthaleneacetic acid		Bean internodes	51 Sulfanilamide		Onion root		
12 Folic acid antagonists		Mouse intestine	52 Theobromine		Onion root	Spindle remnant persists.	
13 Hydroquinone		Mouse intestine	Pycnosis from pre- prophase damage.	53 Nicotine			Pea seedling
14 Neotetrazolium		Onion root		54 Sulfhydryl compounds			Yeasts	Cytoplasmic division enhanced.
15 Urethane		Mouse intestine	Destruction of inter- phase nucleus.	55 Chloracetophenone		Chick osteoblasts	Nuclear recon- struction retarded.
16 Trypaflavine		Onion root		56 Thiourea		Chick fibroblasts	
Prophase				Chromosome Effects Not Confined to One Phase			
17 Dichlorophenoxyacetic acid		Onion root	Prophase blocked.	57 Acenaphthine		Onion root	Breaks.
18 Nitrophenols		Sea urchin egg		58 Acridines		Onion root	
19 Protoanemonin		Corn root	Prophase accelerated.	59 Coumarin		Onion root	
20 Glutathione		Amoeba proteus		60 Phenols		Onion root	
21 Urethane		Rabbit fibroblasts	Precocious chromo- some split.	61 Uracil		Onion root	
22 Tropolones		Tradescantia stamen hairs.		62 Urethane		Bean root	
23 Trypan blue		Rabbit fibroblasts	Spindle formation slowed.	63 Epoxides		Bean root	Rearrangement within chromosome.
24 Aureomycin		Onion root	Membrane disso- lution delayed.	64 Ethoxy caffeine		Onion root	
25 Acridines		Onion root	Reversion to interphase.	65 Mustards		Onion root	
26 Purines		Arbacia egg		66 Urethane		Peony buds	
Metaphase ¹				67 n-Butyl gallate		Onion root	Adhesion.
27 Methyl-naphthoquinone		Onion root	Abnormal chromo- some orientation.	68 Dyes		Onion root	
28 Testosterone, estrone		Rabbit fibroblasts.		69 Acridines		Onion root	Pseudochiasmata.
29 Diphenyl		Wheat root	Rotate spindle.	70 Coumarin		Onion root	
30 Indoleacetic acid		Wheat root		71 Aminoacridine		Onion root	Chromatin diminished.
31 Colchicine		Onion root	72 Aminobenzoate		Onion root		
32 Mustard gas		Chick osteoblasts	Induce monopolar mitotic figure.	73 Phenols		Onion root	Dispersion and despiralization.
33 Narcotics		Onion root		74 Ammonia		Tradescantia hairs	
34 Phenyl urethane		Sea urchin egg		75 Ammonium thiocyanate		Impatiens pollen mother cells	
35 Carbamates		Sea urchin egg		76 Urea		Drosophila salivary glands	
36 Diethyl bromacetyl carbamide		Onion root	Induce multipolar spindle.	77 Glutathione		Worm regenerating tissues		Chromosome widened.
37 Ethyl mercuric phosphate		Corn seedling		78 Antibiotics		Onion root	
38 Methyl-naphthohydroquinone diacetate		Onion root		79 Cysteine		Protozoa	Induced reduction.
39 Streptomycin		Onion root		Revert to interphase.	80 Nucleic acid			Onion root
40 Alcohol		Onion root	81 Acenaphthene			Onion root	Centromere mis- division.
41 DDT		Onion root	82 Mustard			Tradescantia pollen mother cells	

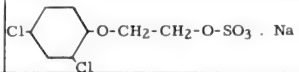
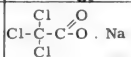
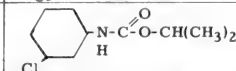
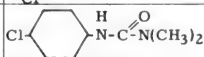
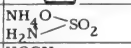
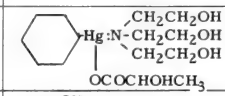
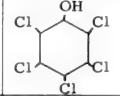
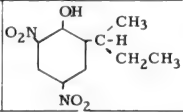
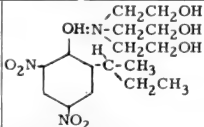
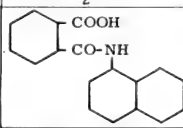
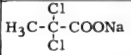
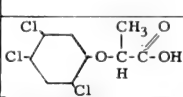

¹/ See Part 2 (below) for metaphase block.

Part II: MITOTIC POISONS: METAPHASE BLOCKING AGENTS

Substance	Concen- tration	Animal	Tissue	Substance	Concen- tration	Plant	Tissue
1 Acenaphthine	Vapor	Drosophila melanogaster		21 Acenaphthine	Saturated	Colchicum	Root
2 Aureomycin	100 ppm	Chick embryo	Fibroblast	22 Aureomycin	50 ppm	Allium cepa	Root
3 Benzene		Mammal	Marrow	23 Benzene	Saturated	Allium sativum	Root
4 Colchicine	10 ⁻⁵ M	Chortophaga viridifasciata	Neuroblast	24 Colchicine	20%	Colchicum autumnale	Root
5 Coumarin	0.1% M	Arbacia punctulata	Egg	25 Coumarin	Saturated	Allium cepa	Root
6 DDT	Saturated	Arbacia punctulata	Egg	26 DDT	Saturated	Allium cepa	Root
7 Dibenzanthracene	0.1%	Chick embryo	Fibroblast	27 Dibenzanthracene	1.5 ppm	Secale cereale	Root
8 p-Dichlorobenzene	Saturated	Paracentrotus lividus	Egg	28 p-Dichlorobenzene	Vapor	Triticum vulgare	Root
9 Epinephrine	0.01%	Chick embryo heart	Fibroblast	29 Epinephrine	1/100	Tradescantia occidentalis	Pollen tube
10 Ethyl-p-aminobenzoate	Saturated	Paracentrotus lividus	Egg	30 Ethyl-p-aminobenzoate	M/400	Allium cepa	Root
11 Hexachlorocyclohexane	0.02%	Sphaerechinus granularis	Egg	31 Hexachlorocyclohexane	10 ⁻⁴ M	Cucurbita pepo	Root
12 Methyl anthranilate	Saturated	Paracentrotus lividus	Egg	32 Methyl anthranilate	Vapor	Linum usitatissimum	
13 Morphine	10 ⁻⁴ M	Chick embryo	Iris epi- thelium	33 Morphine	0.1%	Vicia lutea	Root
14 Naphthoquinone	10 ⁻² M	Tubifex	Egg	34 Naphthoquinone	10 ⁻³ M	Allium cepa	Bud
15 Nicotine	1/8000	Rabbit fibroblast		35 Nicotine	Vapor	Nicotiana tabacum	Root
16 Phenyl urethane	2 x 10 ⁻³ M	Strongylocentrotus lividus	Egg	36 Phenyl urethane	0.02%	Allium cepa	Root
17 Physostigmine	0.1%	Arbacia punctulata	Egg	37 Physostigmine	0.05%	Allium cepa	Root
18 Podophyllotoxin	10 ⁻⁴ mM	Echinarachnius parma	Egg	38 Podophyllotoxin	Saturated	Allium cepa	Root
19 Sulfanilamide		Paracentrotus lividus	Egg		1/2000	Allium cepa	Root

339. HERBICIDES: PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS

Common and [Chemical Name]	Structure	Properties ¹	Solubility ²	Oral Toxicity, Single Dose ³ LD ₅₀ mg/kg	Hazard to Humans ⁴	Type of Activity
1 2, 4-D [2, 4-dichlorophenoxy- acetic acid]		MW=221.0; MP=139.2-140.5; BP=241.49; sp gr=1.565 ³⁰ .	sl. s. w. (0.05%); i. oil; s. acet.	375 rat; 368 mouse; 541 chick; 100 dog; 800 rabbit.	Injurious to eyes; dust, strong sol. irritating to skin, mucous mem- branes; not a sensitizer.	Systemic weed killer.
2 Methyl ester of 2, 4-D [methyl 2, 4-dichloro- phenoxyacetate]		MW=235.0; MP=33-38; BP= 1197; sp gr=1.3706 ^{37.8/4} .	i. w.; v. s. aromatic oils.	650 g. pig.	Very slight; concentrate causes transient injury to eyes, irritation to skin.	Systemic weed killer.
3 Isopropyl ester of 2, 4-D [isopropyl 2, 4-di- chlorophenoxyacetate]		MW=263.1; MP=22.8 (fr. p.); BP=170 ¹⁰ ; sp gr=1.251 ²⁰ (com'l).	i. w.; s. kerosene; v. s. xylene.	700 rat; 541 mouse; 550 g. pig; 1420 chick.	Concentrate slightly irritating to skin upon prolonged contact.	Systemic weed killer.
4 n-Butyl ester of 2, 4-D [n-butyl 2, 4-dichloro- phenoxyacetate]		MW=277.1; MP=9 (fr. p.); BP=160-170 ¹⁵⁻² ; sp gr= 1.23525 ⁴ .	i. w.; s. kerosene; v. s. xylene.	620 rat; 848 g. pig; 424 rabbit.	Concentrate slightly irritating to skin upon prolonged contact.	Systemic weed killer.
5 Propylene glycol butyl ether esters of 2, 4-D [poly-propylene glycol butyl ether 2, 4-di- chlorophenoxyacetate]		MW=356(av.); liquid; sp gr=1.188 ²⁰ .	i. w.; s. kerosene; v. s. xylene.	570 rat.	Concentrate causes transient injury to eyes; slightly irritating to skin upon prolonged exposure.	Systemic weed killer.
6 2-Butoxyethyl ester of 2, 4-D [2-butoxyethyl 2, 4-dichlorophenoxy- acetate]		MW=321.2; liquid.	i. w.; s. kerosene; v. s. xylene.		Concentrate causes transient injury to eyes; slightly irritating to skin upon prolonged exposure.	Systemic weed killer.
7 Triethanolamine salt of 2, 4-D [2, 4-dichlorophen- oxyacetic acid tri- ethanolamine salt]		MW=361-366 ⁵ ; MP=142-144; sp gr=1.237 ²⁰ .	v. s. w.; i. oil.	2000 g. pig; 500+ chick.	Injurious to eyes; irritating to skin upon prolonged contact.	Systemic weed killer.
8 2, 4, 5-T [2, 4, 5-trichloro- phenoxyacetic acid]		MW=255.5; MP=153.5-155; sp gr=1.80 ²⁰ .	sl. s. w. (0.02%); sl. s. oil.	500 rat; 389 mouse; 381 g. pig; 100 dog.	Injurious to eyes; dust and concentrate irritating to skin, throat, lungs.	Systemic weed killer.
9 Methyl ester of 2, 4, 5-T [methyl 2, 4, 5-trichloro- phenoxyacetate]		MW=269.5; MP=89-90.	i. w.; sl. s. kero- sene; s. xylene.			Systemic weed and woody plant killer.
10 Isopropyl ester of 2, 4, 5-T [isopropyl 2, 4, 5-trichloro- phenoxyacetate]		MW=297.6; MP=42-43; BP= 157 ²⁰ ; sp gr=1.243- 1.26 ²⁰ .	i. w.; sl. s. kero- sene; s. xylene.	495 rat; 551 mouse; 449 g. pig; 850 chick.	Transient injury to eyes from concentrate; slightly irritating to skin upon prolonged contact.	Systemic weed killer.
11 Propylene glycol butyl ether esters of 2, 4, 5-T [poly-propylene glycol butyl ether 2, 4, 5-tri- chlorophenoxyacetate]		MW=390.5(av.); liquid; BP= 193-200 ^{2.5} ; sp gr=1.24- 1.25 ²⁰ .	i. w.; s. kerosene; v. s. xylene.	890 rat; 820 mouse; 1000 g. pig; 360 rabbit; 2400 chick.	Transient injury to eyes from concentrate; slightly irritating to skin upon prolonged contact.	Systemic weed and woody plant killer.
12 MCPA [2-methyl-4- chlorophenoxyacetic acid]		MW=200.6; MP=119-120; sp gr=1.35 ¹⁵ .	sl. s. w. (0.1%); i. oil.	700 rat.	Injurious to eyes; concentrate slightly irritating to skin upon long contact.	Systemic weed killer.
13 Triethanolamine salt of MCPA [4-chloro-O- toloxyacetic acid tri- ethanolamine salt]		MW=340.6-345.6 ⁵ ; sp gr= 1.206 ²⁰ .	v. s. w.; i. oil.	1200 rat.	Injurious to eyes; concentrate slightly irritating to skin upon long contact.	Systemic weed killer.
14 Maleic hydrazide (MH) [1, 2-dihydropyridazine- 3, 6-dione]		MW=112; MP=290-295; sp gr=1.60 ²⁵ (tech. grade).	sl. s. w. (0.6%); i. acet.	5800 rat.	No effect on eyes or skin.	Translocated.

15	2, 4-DES [sodium-2, 4-dichlorophenoxy-ethyl sulfate]		MW=309;MP=170;density approx. 27 lb/cu ft; purity=90% +.	s. w. (25%); i. oil.	730-1400 rat; 250 rabbit.	Injurious to eyes and skin.	Translocated through roots; pre-emergence weed killer.
16	Sodium TCA [sodium trichloroacetate]		MW=185.4;MP=d.; purity=90% minimum.	v. s. w.; i. oil.	5000 rat;3640 mouse;4280 chick.	Concentrate injurious to eyes; irritating to skin.	Translocated through roots; pre-emergence.
17	CIPC [isopropyl N-(3-chlorophenyl)-carbamate]		MW=213.6;MP=41.4;BP=247 d.; sp gr=1.18 ^{30/20} ; purity=98-99%.	sl. s. w. (108 ppm); v. s. aromatic solvents.	5000-7000 rat; 5000 rabbit.	No hazard to skin. No problem from absorption or sensitization.	Residual pre-emergence; translocated through roots.
18	Monuron [3-(p-chlorophenyl)-1,1-dimethyl-urea]		MW=198.6;MP=170;sp gr=1.25;purity=80%.	sl. s. w. (230 ppm); sl. oil (229 ppm).	3500 rat;670 g. pig;1500 rabbit.	None. No problem from absorption or sensitization.	Translocated; sterilant; residual pre-emergence.
19	[Ammonium sulfamate]		MW=114.3;MP=131-132 (tech.);purity=80%.	s. w. (232 g/100 g).	3900 rat.	No hazard to skin from irritation; not a sensitizer.	Translocated; contact sterilant.
20	[Potassium cyanate]	KOCN	MW=81.1;MP=315;sp gr=2.056;purity=92%.	s. w. (72%);i. oil; sl. s. bz., al.	780 [±] rat;1050 mouse;230 [±] rabbit.	-	Contact.
21	[Phenylmercuri-triethanolammonium lactate]		MW=515;MP=126;purity=99%.	v. s. w.;sl. s. oil; s. al., gly, glycols.	>0.67 g. pig; >0.10 monkey.	Seriously injurious to eyes; concentrate seriously injurious to skin; readily absorbed through skin.	Contact; translocated through roots.
22	PCP [pentachlorophenol]		MW=266.3;MP=191;BP=310 d.; sp gr=1.949 ²⁵ ; purity=83%.	sl. s. w. (15 ppm); s. xylene, acet.	50-500 rat, g. pig, rabbit; chick.	Injurious to eyes; concentrate injurious to skin; toxic amounts readily absorbed through skin. Poisonous to humans and other warm-blooded animals.	Contact and/or pre-emergence weed killer; translocated through roots.
23	DNBP [4, 6-dinitro-2-sec.-butylphenol]		MW=239.1;MP=39.3±0.3; BP=d.;purity=95%.	l. w.;s. oil, kerosene;v. s. xylene.	40 rat;25 g. pig;26 chick.	Painful, not injurious to eyes; not irritating to skin, but readily absorbed in toxic amounts. Poisonous to humans and other warm-blooded animals.	Contact and/or pre-emergence weed killer.
24	Triethanolamine salt of 4, 6-dinitro-2-sec.-butyl phenol [triethanolammonium 4, 6-dinitro-2-sec.-butylphenate]		MW=378.1;sp gr=1.104 ²⁰ ; purity=3 lb/gal DNBP	v. s. w.; i. oil.	45 rat;35 g. pig;28 chick.	Same as DNBP (above).	Contact and/or pre-emergence weed killer.
25	NPA [N-(1-naphthyl)-phthalamic acid]		MW=291.4;MP=175-180; sp gr=1.35-1.45;purity=95% minimum.	sl. s. w. (0.02%); sl. s. organic solvents.	>8200 (test animal not specified).	No hazard to skin; not absorbed.	Selective systemic pre-emergence weed killer.
26	Dalapon, sodium salt [sodium 2, 2-dichloropropionate]		MW=164.9;MP=193-197; purity=68% in formulations.	s. w. (50%); sl. s. oil (0.25%).	6590-8120 rat; >4000 mouse; 3360 g. pig; 5660 chick.	Irritating and injurious to eyes; concentrate irritating to skin; no problem from absorption.	Systemic post- and pre-emergence weed killer.
27	2-(2, 4, 5-TP) [2-(2, 4, 5-trichlorophenoxy)propionic acid]		MW=268.4;MP=179-181; purity=95%+.	i. w., oil.	650 rat; 600-1400 (esters) rat, g. pig, mouse, chick.	Concentrate injurious to eyes; irritating to skin upon prolonged contact.	Systemic weed and woody plants killer.
28	[Ethyl xanthogen disulfide]	(C ₂ H ₅ OCS ₂) ₂	MW=242.4 (calc.);MP=27-29;BP=112 d.; sp gr=1.26 ²⁵ /15.5;purity=80%.	i. w.; 100% s. bz., acet.	603 rat;504 g. pig;781 rabbit.	Concentrate irritating and readily absorbed in toxic amounts. It is a sensitizer.	Contact, some pre-emergence.
29	Cyanamid [calcium cyanamide]	Not established. May be CaN-CN or 	MW=80.1;MP=1300 (subl.); sp gr=2.3;purity 44-57%.	sl. s. w.; i. al.	1400 rabbit.	Injurious to eyes; concentrate irritating and injurious to skin on long contact.	Contact; pre-planting sterilant.
30	[Methyl bromide]	CH ₃ Br	MW=95.0;MP=-93(fr. p); BP=3.5760;sp gr=1.732 ^{0/0} .	sl. s. w. (0.09%); s. bz.	75 g. pig; 50 rabbit.	Injurious to eyes; concentrate injurious to skin on prolonged contact. Poisonous.	Sterilant (seeds).
31	Stoddard solvent		MP=not more than 50% distilled at 177°C;sp gr=0.784 ^{16/16} .	i. w.	2000 rat.	Irritant upon prolonged or repeated exposure.	Contact selective.

/1/ av.=average;BP=boiling point, °C, with superscript, where present, indicating pressure; calc.=calculated; com=l=commercial; d.=decomposes; fr. p.=freezing point; MP=melting point; MW=molecular weight; sp gr =specific gravity (or density), with superscript indicating temperature of measurement (for liquids, sp gr of the solution is referred to that of water at the same temperature, unless otherwise indicated); subl.=sublimes, tech.=technical. /2/ acet.=acetone; al.=ethyl alcohol(95%); arom.=aromatic; bz.=benzene; gly.=glycerol; i.=insoluble; ppm=parts per million; s.=soluble; sl.=slightly; sol.=solution; solv.=solvent(s); v.=very; w.=water. /3/ g. pig=guinea pig. /4/ sol.=solution. /5/ Refers to 4 lb acid equivalent aqueous formulation.

340. RESPONSE TO 2,4-D: VARIOUS WEEDS AND UNDESIRABLE WOODY PLANTS

Data are based upon separate lists compiled and issued during 1949-1955 by weed control conferences of United States and Canada. Classifications and terminologies used by the various conferences differ and have undergone modification. For purposes of this table the following general descriptive terms apply: S = species can be killed by relatively low concentrations of at least one formulation of 2,4-D in one or more foliage applications and at some stage of growth other than the seedling stage (during which many resistant and intermediate species are susceptible); I = species is severely injured or controlled by above treatments or can be killed by one or more foliage applications of higher concentrations (woody plants and herbaceous perennials frequently show response in top kill only); R = species is only slightly or not at all damaged by foliage applications, and control by 2,4-D is not feasible. Species resistant to 2,4-D are listed in Fn 1 appearing on page 396. Low concentrations range up to 1 lb acid equivalent per acre or 1 lb acid equivalent in 100 gal carrier (for woody plants). Higher concentrations range from 1-4 lb/acre (or 1-4 lb/100 gal) in many parts of the country. Still higher concentrations for control of woody plants may range from 3-16 lb/100 gal carrier, depending on species and method of application. Variations in response (e.g., more than one classification symbol) may be attributed to differences in climatic conditions, soil properties, varieties, or to ecotypes within the species.

Species ¹	Response	Species ¹	Response
Annual and Winter Annual Weeds		Annual and Winter Annual Weeds (concluded)	
1 Bassia, five-hooked (<i>Bassia hyssopifolia</i>)	I	66 Mustard, blue (<i>Chorispora tenella</i>)	S
2 Bedstraw (<i>Galium</i> spp)	I	67 Mustard, hares-ear (<i>Conringia orientalis</i>)	S
3 Beepplant, Rocky Mountain (<i>Cleome serrulata</i>)	S	68 Mustard, tansy (<i>Descurainia pinnata</i>)	S
4 Beet, wild (<i>Beta maritima</i>)	I	69 Mustard, tumbling (<i>Sisymbrium altissimum</i>)	S
5 Beggar-tick (<i>Bidens frondosa</i>)	I	70 Mustard, field (charlock) (<i>Brassica arvensis</i>)	S
6 Bitterweed (<i>Helenium tenuifolium</i>)	S	71 Mustard, wild (<i>B. kaberi</i>)	S
7 Buckwheat, wild (<i>Polygonum convolvulus</i>)	I, R	72 Mustard, wormseed (<i>Erysimum cheiranthoides</i>)	S
8 Bur, blue [stickseed] (<i>Lappula echinata</i>)	S	73 Nightshade, black (<i>Solanum nigrum</i>)	S, R
9 Bush, burning [annual kochia] (<i>Kochia scoparia</i>)	S	74 Nightshade, cut-leaved (<i>S. triflorum</i>)	I
10 Buttercup, field (<i>Ranunculus arvensis</i>)	S	75 Nightshade, hairy (<i>S. vilosum</i>)	I
11 Butterfly weed (<i>Gaura parviflora</i>)	S	76 Orache [saltbush] (<i>Atriplex hastata</i>)	S
12 Buttons, Australian brass (<i>Cotula australis</i>)	S	77 Ox-tongue, bristly (<i>Picris echinodes</i>)	S
13 Careless weed (<i>Amaranthus palmerii</i>)	S	78 Peppergrass (<i>Lepidium</i> spp)	S
14 Carpetweed (<i>Mollugo verticillata</i>)	I, R	79 Pigweed, prostrate (<i>Amaranthus blitoides</i>)	I
15 Cheeseweed (<i>Malva parviflora</i>)	S	80 Pigweed, rough (<i>A. retroflexus</i>)	S, I
16 Chickweed, common (<i>Stellaria media</i>)	S, I	81 Pigweed, tumbling (<i>A. graecizans</i>)	S, I
17 Cinquefoil, rough (<i>Potentilla monspeliensis</i>)	S	82 Pimpernel (<i>Anagallis arvensis</i>)	I
18 Clover, bur (<i>Medicago hispida</i>)	S	83 Pineapple weed [wild marigold] (<i>Matricaria matricarioides</i>)	S
19 Clover, sour (<i>Melilotus indica</i>)	I	84 Poppy, Roemeria (<i>Roemeria refracta</i>)	S
20 Cocklebur (<i>Xanthium</i> spp)	S	85 Poppy, white prickly (<i>Argemone intermedia</i>)	I
21 Cockle, purple [corncockle] (<i>Agrostemma githago</i>)	I, R	86 Primrose, cut-leaved (<i>Oenothera lacinata</i>)	S
22 Coreopsis (<i>Coreopsis tinctoria</i>)	I	87 Puncture vine [goat-head, bull-head, galtrop] (<i>Tribulus terrestris</i>)	S
23 Corn flower (<i>Centaurea cyanus</i>)	I	88 Purslane (<i>Portulaca oleracea</i>)	I, R
24 Cucumber, wild (<i>Sicyos angulatus</i>)	S	89 Radish, wild (<i>Raphanus raphanistrum</i>)	S
25 Dodders (<i>Cuscuta</i> spp)	I	90 Ragweed, common (<i>Ambrosia artemisiifolia</i>)	S, I, R
26 Elder, marsh (<i>Iva xanthifolia</i>)	S	91 Ragweed, giant (<i>A. trifida</i>)	S
27 Fanweed [Frenchweed, stinkweed, pennycress] (<i>Thlaspi arvense</i>)	S	92 Rape, annual (<i>Brassica napus</i>)	S
28 Fiddleneck (<i>Amsinckia</i> spp)	I	93 Rape, bird's [common yellow mustard] (<i>Brassica campestris</i>)	S
29 Filaree, red stem [storksbill] (<i>Erodium cicutarium</i>)	I	94 Redweed (<i>Melochia corchorifolia</i>)	S
30 Filaree, white stem [storksbill] (<i>E. moschatum</i>)	I	95 Rocket, London (<i>Sisymbrium irio</i>)	S
31 Flax, false (<i>Camelina</i> spp)	I	96 Rocket, yellow (<i>Barbarea vulgaris</i>)	S
32 Fleabane, Canada (<i>Erigeron canadensis</i>)	I	97 Saltbush (<i>Atriplex</i> spp)	S
33 Fleabane, daisy and others (<i>E. annuus</i> , <i>Erigeron</i> spp)	I	98 Shepherd's purse (<i>Capsella bursa-pastoris</i>)	S, I
34 Flower-of-an-hour [bladder Ketmia] (<i>Hibiscus trionum</i>)	S	99 Smartweed [lady's thumb and others] (<i>Polygonum persicaria</i>)	I, R
35 Foxtail, yellow (<i>Setaria glauca</i>)	I, R	100 Speedwells (<i>Veronica</i> spp)	I
36 Galinsoga (<i>Galinsoga parviflora</i>)	S	101 Spikeweed, common (<i>Centromadia pungens</i>)	I
37 Goatsbeard (<i>Tragopogon</i> spp)	S	102 Spurge, mat (<i>Euphorbia glyptosperma</i>)	I
38 Goosefoot, narrow-leaved (<i>Chenopodium leptophyllum</i>)	S	103 Spurge, spotted (<i>E. maculata</i>)	I, R
39 Goosefoot, nettleleaf (<i>C. murale</i>)	S	104 Sunflower, wild (<i>Helianthus annuus</i>)	S
40 Goosefoot, oak-leaved (<i>C. glaucum</i>)	I	105 Telegraph plant (<i>Heterotheca grandiflora</i>)	I
41 Gromwell, corn (<i>Lithospermum arvense</i>)	I	106 Thistle, blessed (<i>Cnicus benedictus</i>)	I
42 Groundcherry (<i>Physalis</i> spp)	S	107 Thistle, distaff (<i>Carthamus lanatus</i>)	I
43 Halogeton (<i>Halogeton glomeratus</i>)	S	108 Thistle, milk (<i>Silybum marianum</i>)	S
44 Hemp (<i>Cannabis sativa</i>)	I	109 Thistle, Russian (<i>Salsola kali</i>)	S, I
45 Henbit [dead-nettle] (<i>Lamium amplexicaule</i>)	I	110 Thistle, sow [common, annual] (<i>Sonchus oleraceus</i>)	S
46 Indigo [coffee-weed] (<i>Sesbania macrocarpa</i>)	S	111 Thistle, sow [spiny or prickly] (<i>S. asper</i>)	S, I
47 Indigo, curly (<i>Aeschynomene virginica</i>)	I	112 Thistle, yellow star (<i>Centaurea solstitialis</i>)	S
48 Jewelweed (<i>Impatiens pallida</i>)	S	113 Tocalote (<i>C. melitensis</i>)	I
49 Jimson weed (<i>Datura stramonium</i>)	S	114 Vervain (<i>Verbena bracteosa</i>)	S
50 Knotweed, common [doorweed] (<i>Polygonum aviculare</i> , <i>P. erectum</i>)	I, R	115 Vetches, wild (<i>Vicia</i> spp)	S
51 Knotweed, silver-sheathed (<i>P. argyrocoleon</i>)	I, R	116 Wintercress, bitter (<i>Barbarea vulgaris</i>)	S
52 Lamb's quarter (<i>Chenopodium album</i>)	S, I	117 Wormwood (<i>Artemisia</i> spp)	S
53 Lettuce, prickly (<i>Lactuca scariola</i>)	S, I	Herbaceous Biennial and Perennial Weeds	
54 Lettuce, wild (<i>Lactuca</i> spp)	I	118 Agroseris (<i>Agroseris</i> spp)	S
55 Mallow (<i>Malva neglecta</i>)	I	119 Alfalfa (<i>Medicago</i> spp)	S
56 Mallow, bull (<i>M. borealis</i>)	S	120 Alligator weed (<i>Alternanthera piloxeroides</i>)	I
57 Mallow, Indian [velvetleaf, butterprint] (<i>Abutilon theophrasti</i>)	S	121 Arrowhead [arrow weed] (<i>Sagittaria</i> spp)	I
58 Mallow, roundleaved or common (<i>Malva rotundifolia</i>)	S, I	122 Artichoke, Jerusalem (<i>Helianthus tuberosus</i>)	S
59 Mare's-tail [Canada fleabane] (<i>Erigeron canadensis</i>)	I	123 Aster (<i>Aster</i> spp)	I
60 Mayweed [dog fennel] (<i>Anthemis cotula</i>)	I	124 Aster, woody (<i>Xylorrhiza parryi</i>)	S
61 Medic, black [yellow trefoil] (<i>Medicago lupulina</i>)	S	125 Avena, three-flowered (<i>Geum triflorum</i>)	I
62 Mexican weed (<i>Caperonia castaneaefolia</i>)	S	126 Bedstraws, northern (<i>Galium boreale</i>)	I, R
63 Morning-glory, annual (<i>Ipomoea</i> spp)	S	127 Bindweed, field [small flowered morning-glory] (<i>Convolvulus arvensis</i>)	S, I
64 Mellein, turkey (<i>Eremocarpus setigerus</i>)	S	128 Bindweed, hedge [large flowered morning-glory] (<i>C. sepium</i>)	S
65 Mustard, ball (<i>Neslia paniculata</i>)	S	129 Biscuit root (<i>Lomatium leptocarpum</i>)	S

340. RESPONSE TO 2,4-D: VARIOUS WEEDS AND UNDESIRABLE WOODY PLANTS (Continued)

Data are based upon separate lists compiled and issued during 1949-1955 by weed control conferences of United States and Canada. Classifications and terminologies used by the various conferences differ and have undergone modification. For purposes of this table the following general descriptive terms apply: S = species can be killed by relatively low concentrations of at least one formulation of 2,4-D in one or more foliage applications and at some stage of growth other than the seedling stage (during which many resistant and intermediate species are susceptible); I = species is severely injured or controlled by above treatments or can be killed by one or more foliage applications of higher concentrations (woody plants and herbaceous perennials frequently show response in top kill only); R = species is only slightly or not at all damaged by foliage applications, and control by 2,4-D is not feasible. Species resistant to 2,4-D are listed in Fn 1 appearing on page 396. Low concentrations range up to 1 lb acid equivalent per acre or 1 lb acid equivalent in 100 gal carrier (for woody plants). Higher concentrations range from 1-4 lb/acre (or 1-4 lb/100 gal) in many parts of the country. Still higher concentrations for control of woody plants may range from 3-16 lb/100 gal carrier, depending on species and method of application. Variations in response (e.g., more than one classification symbol) may be attributed to differences in climatic conditions, soil properties, varieties, or to ecotypes within the species.

Species ¹	Response	Species ¹	Response
Herbaceous Biennial and Perennial Weeds (continued)		Herbaceous Biennial and Perennial Weeds (concluded)	
130 Blueweed (<i>Echium vulgare</i>)	I	196 Milkweed, whorled (<i>Asclepias verticillata</i>)	S, R
131 Blueweed (<i>Helianthus ciliaris</i>)	I	197 Moonseed (<i>Menispermum canadense</i>)	S
132 Bouncing Bet (<i>Saponaria officinalis</i>)	I	198 Mule's ear (<i>Wyethia amplexicaule</i>)	S
133 Buckwheat, false (<i>Polygonum scandens</i>)	I	199 Mullein, common [Mullen] (<i>Verbascum thapsus</i>)	S, R
134 Burdock (<i>Arctium minus</i>)	S	200 Nettle, hedge (<i>Stachys palustris</i>)	S
135 Burnet (<i>Sanguisorba minor</i>)	S	201 Nettle, stinging (<i>Urtica dioica</i>)	S
136 Buttercup, tall and others (<i>Ranunculus acris</i> , R. spp)	I	202 Nettle, stinging (<i>U. gracilis</i>)	I
137 Camas, death (<i>Zygadenus gramineus</i>)	S	203 Nettle, white horse (<i>Solanum elaeagnifolium</i>)	S, R
138 Carrot, false (<i>Pseudocymopterus montanus</i>)	S	204 Nutgrass, northern (<i>Cyperus esculentus</i>)	I
139 Carrot, wild (<i>Daucus carota</i>)	S	205 Nutgrass, southern (<i>C. rotundus</i>)	I
140 Catnip (<i>Nepeta cataria</i>)	S	206 Onion, wild (<i>Allium canadense</i>)	I
141 Cattail (<i>Typha</i> spp., esp. <i>T. latifolia</i>)	I	207 Onion, wild (<i>A. acuminatum</i>)	S
142 Chickweed, field (<i>Cerastium arvense</i>)	S, I	208 Parsnip, wild (<i>Pastinaca sativa</i>)	S
143 Chickweed, mouse-ear (<i>C. vulgatum</i>)	S, I, R	209 Pentstemon, Rydberg (<i>Pentstemon rydbergii</i>)	S
144 Chicory (<i>Cichorium intybus</i>)	S	210 Pennywort, lawn (<i>Hydrocotyle rotundifolia</i>)	S
145 Cinquefoil [fivefingers] (<i>Potentilla filipes</i> , P. glaucophylla)	S	211 Pignut, Indian (<i>Hoffmannseggia densiflora</i>)	S
146 Cinquefoil, silvery (<i>P. argetea</i>)	I	212 Plantains, common (<i>Plantago major</i>)	S
147 Comfrey (<i>Symphytum officinale</i>)	I	213 Plantains (English) [buckhorn] (<i>P. lanceolata</i>)	S
148 Coneflowers (<i>Ratibida</i> spp)	S	214 Pokeweed (<i>Phytolacca americana</i>)	I
149 Cress, Austrian field (<i>Roripa austriaca</i>)	S	215 Potato, wild sweet [man-of-the-earth] (<i>Ipomoea pandurata</i>)	S, I
150 Cress, hoary [whiteweed] (<i>Lepidium draba</i> , <i>Cardaria draba</i>)	S, I, R	216 Poverty weed (<i>Iva axillaris</i>)	S, I, R
151 Cress, western yellow (<i>Radicula sylvestris</i>)	I	217 Poverty weed, silver-leaved [white franseria] (<i>Franseria discolor</i>)	S
152 Daisy, ox-eye (<i>Chrysanthemum leucanthemum</i>)	I, R	218 Primrose, evening (<i>Oenothera</i> spp)	S
153 Dandelions (<i>Taraxacum</i> spp., esp. <i>T. officinale</i>)	S	219 Puccoon, hoary (<i>Lithospermum canescens</i>)	I
154 Dandelion, fall (<i>Leontodon autumnalis</i>)	S	220 Ragweed, bur [Woolly-leaved poverty weed] (<i>Franseria tomentosa</i>)	I
155 Dock, curled and others (<i>Rumex crispus</i> , R. spp)	I	221 Ragweed, false (<i>Iva ciliata</i>)	S
156 Dogbane (<i>Apocynum cannabinum</i>)	S, I	222 Ragweed, western [perennial] (<i>Ambrosia psilostachya</i>)	S
157 Dragonhead (<i>Dracocephalum parviflorum</i>)	S	223 Ragwort, tansy (<i>Senecio jacobaea</i>)	I, R
158 Fleabane (<i>Erigeron</i> spp)	S	224 Rocket, yellow (<i>Barbarea vulgaris</i>)	I
159 Fiddleneck (<i>Amsinkia</i> spp)	S	225 Rosin weed (<i>Silphium</i> spp)	S
160 Figwort (<i>Scrophularia lanceolata</i>)	S	226 Rush, slender (<i>Juncus tenuis</i>)	S
161 Four-o'clock (<i>Mirabilis jalapa</i>)	S	227 Sage, pasture (<i>Artemisia frigida</i>)	S, I, R
162 Garlic, wild (<i>Allium vineale</i> , <i>Allium</i> spp)	S, I	228 Sage, sand (<i>A. gnaphaloides</i>)	S
163 Gaura (<i>Gaura</i> spp)	S	229 St. John's-wort [klamath weed, goatweed] (<i>Hypericum perforatum</i>)	S, R
164 Geranium [cranesbill] (<i>Geranium carolinianum</i>)	I	230 Skeleton weed (<i>Lygodesmia juncea</i>)	I
165 Goatsbeard (<i>Tragopogon</i> spp)	S, I	231 Smartweed, swamp [tanweed] (<i>Polygonum coccineum</i> , <i>P. mühlenbergia</i>)	I, R
166 Goatsrue (<i>Galega officinalis</i>)	S	232 Sneezeweed, orange (<i>Helenium hoopesii</i>)	S, I
167 Goldaster, hairy (<i>Chrysopsis villosa</i>)	S	233 Sorrel, sheep (<i>Rumex acetosella</i>)	I, R
168 Goldenrods (<i>Solidago</i> spp)	S, I	234 Spurge, leafy (<i>Euphorbia esula</i>)	I, R
169 Gourd, wild (<i>Cucurbita foetidissima</i>)	I	235 Stonecrop (<i>Sedum acre</i>)	S
170 Groundcherry, perennial (<i>Physalis</i> spp)	I, R	236 Sunflower, false (<i>Heliopsis scabra</i>)	S
171 Gumweed (<i>Grindelia squarrosa</i> , <i>G. perennis</i>)	S	237 Sunflower, perennial (<i>Helianthus</i> spp, H. maximiliani, H. grosseserratus)	S
172 Hawkweed, orange (<i>Hieracium aurantiacum</i>)	S, I	238 Sweetclover (<i>Melilotus</i> spp)	S
173 Heal-all (<i>Prunella vulgaris</i>)	S	239 Teasel (<i>Dipsacus sylvestris</i>)	I
174 Hemlock, poison (<i>Conium maculatum</i>)	S	240 Thistle, artichoke [cardo] (<i>Cynara cardunculus</i>)	S
175 Hemlock, water (<i>Cicuta</i> spp)	S	241 Thistle, biennial (<i>Cirsium</i> spp)	S
176 Horsetail (<i>Equisetum</i> spp)	S, I	242 Thistle, bull (<i>Cirsium lanceolatum</i>)	S, I
177 Hound's-tongue (<i>Cynoglossum officinale</i>)	I	243 Thistle, bull (<i>C. vulgare</i>)	I
178 Hyacinth, water (<i>Eichhornia crassipes</i>)	S	244 Thistle, Canada (<i>C. arvense</i>)	I
179 Iron weed (<i>Veronica baldwinii</i>)	I	245 Thistle, perennial sow (<i>Sonchus arvensis</i>)	S, I
180 Ivy, ground [creeping Charlie] (<i>Glechoma hederacea</i> , <i>Nepeta hederacea</i>)	S, I	246 Tule (<i>Scirpus acutus</i>)	I
181 King devil [yellow-flowered hawkweed] (<i>Hieracium spp</i>)	I	247 Vervains (<i>Verbena</i> spp)	S, I, R
182 Knapweeds [esp. Russian knapweed] (<i>Centaurea</i> spp, C. picris)	S, I, R	248 Vetch, two-grooved (<i>Astragalus bisulcatus</i>)	S
183 Larkspur, low (<i>Delphinium geyeri</i>)	S, I, R	249 Vetch, narrow-leaved (<i>A. bipinnata</i>)	S
184 Larkspur, Menzies (<i>D. menziesii</i>)	S	250 Vetch, crown (<i>Coronilla varia</i>)	S
185 Larkspur, tall (<i>D. barbeyi</i>)	S	251 Vetch, wild (<i>Vicia</i> spp)	S
186 Lettuce, blue (<i>Lactuca pulchella</i>)	S, I	252 Wormwood, biennial (<i>Artemisia biennis</i>)	S, I
187 Licorice, wild (<i>Glycyrrhiza lepidota</i>)	S	253 Yarrow, common (<i>Achillea millefolium</i>)	I, R
188 Locoweed (<i>Oxytropis lambertii</i>)	S	254 Yarrow, western (<i>A. lanulosa</i>)	S
189 Loosestrife, purple (<i>Lythrum salicaria</i>)	I	Woody Plants	
190 Lupine, mountain (<i>Lupinus alpestris</i>)	S	255 Alder (<i>Alnus</i> spp)	S
191 Lupine, silvery (<i>L. argentus</i>)	S	256 Apple, American crab (<i>Pyrus coronaria</i>)	S
192 Mallow, poppy (<i>Callirhoe involucrata</i>)	S	257 Aspen (<i>Populus</i> spp., esp. <i>P. tremuloides</i>)	S
193 Mallow, round-leaved or common (<i>Malva neglecta</i>)	S, I	258 Barberry, common and others (<i>Berberis vulgaris</i> , <i>Berberis</i> spp)	I, R
194 Milkweed, purple-flowered (<i>Asclepias purpurea</i>)	I		
195 Milkweed, woolly-pod (<i>A. eriocarpa</i>)	S		

340. RESPONSE TO 2,4-D: VARIOUS WEEDS AND UNDESIRABLE WOODY PLANTS (Concluded)

Data are based upon separate lists compiled and issued during 1949-1955 by weed control conferences of United States and Canada. Classifications and terminologies used by the various conferences differ and have undergone modification. For purposes of this table the following general descriptive terms apply: S = species can be killed by relatively low concentrations of at least one formulation of 2,4-D in one or more foliage applications and at some stage of growth other than the seedling stage (during which many resistant and intermediate species are susceptible); I = species is severely injured or controlled by above treatments or can be killed by one or more foliage applications of higher concentrations, (woody plants and herbaceous perennials frequently show response in top kill only); R = species is only slightly or not at all damaged by foliage applications, and control by 2,4-D is not feasible. Species resistant to 2,4-D are listed in Fn 1 appearing on page 396. Low concentrations range up to 1 lb acid equivalent per acre or 1 lb acid equivalent in 100 gal carrier (for woody plants). Higher concentrations range from 1-4 lb/acre (or 1-4 lb/100 gal) in many parts of the country. Still higher concentrations for control of woody plants may range from 3-16 lb/100 gal carrier, depending on species and method of application. Variations in response (e.g., more than one classification symbol) may be attributed to differences in climatic conditions, soil properties, varieties, or to ecotypes within the species.

Species ¹		Response	Species ¹		Response
Woody Plants (continued)			Woody Plants (concluded)		
259	Barberry, native [Colorado] (Berberis fendleri)	S	302	Hazel (Corylus spp)	S
260	Basswood (Tilia americana)	I, R	303	Hickory (Carya spp)	S, I, R
261	Birch (Betula spp)	S	304	Honeysuckle (Lonicera japonica)	S
262	Blackberry, common (Rubus spp)	I, R	305	Honeysuckle, bush (Diervilla lonicera)	S
263	Blueberry (Vaccinium spp)	S	306	Hornbeam (Ostrya virginiana)	S
264	Brier, common, green (Smilax rotundifolia)	I	307	Ivy, poison (Rhus radicans, R. toxicodendron)	S, I
265	Broom, Scotch (Cytisus spp)	I	308	Juneberry (Amelanchier alnifolia)	S
266	Buckbrush [coralberry, Indian currant] (Symphoricarpos orbiculatus)	I	309	Lambkill [laurel, sheep] (Kalmia angustifolia)	S, R
267	Buckbrush, western [western snowberry, wolfberry] (S. occidentalis)	S	310	Lead plant (Amorpha canescens)	S
268	Burroweed (Haplopappus tenuisectus)	I	311	Lilac (Syringa vulgaris)	R
269	Cactus, cholla (Opuntia imbricata)	I	312	Locust, black (Robinia pseudoacacia)	S
270	Ceanothus, wedgeleaf (Ceanothus cuneatus)	I	313	Lotebush (Condalia obtusifolia)	S, I
271	Cedar, salt (Tamarix gallica)	S	314	Maple (Acer spp)	I, R
272	Cherry, wild [black and red] (Prunus spp)	I	315	Maple, Manitoba (A. negundo)	S
273	Chestnut (Castanea dentata)	I	316	Mesquite, honey (Prosopis juliflora var. glandulosa)	S, I
274	Chokecherry (Prunus virginiana)	S	317	Mulberry (Morus spp)	I
275	Cottonwood (Populus spp)	S	318	Myrtle, wax (Myrica cerifera)	S
276	Creeper, Virginia (Parthenocissus quinquefolia)	S	319	Oak, black jack (Quercus marilandica)	S, I
277	Currant, Alpine (Ribes montigenum)	I, R	320	Oak, post (Q. stellata)	I
278	Currant, American black (R. americanum)	S	321	Oak, laurel (Q. imbricaria)	I
279	Currant, Hudson Bay (R. hudsonianum)	S	322	Oak, white (Q. alba)	I
280	Currant, prickly (R. lacustre)	I, R	323	Oak, scrub (Q. illicifolia)	I
281	Currant, red-flowered (R. sanguineum)	S	324	Plum, wild (Prunus spp)	S, I
282	Currant, red swamp (R. triste)	S	325	Poplar, balsam (Populus balsamifera)	I
283	Currant, Sierra Nevada (R. nevadense)	S	326	Prickly-ash, northern (Xanthoxylum americanum)	I
284	Currant, squaw (R. cereum)	S	327	Rose, Cherokee (Rosa laevigata)	S
285	Currant, stink (R. brateosum)	S	328	Sage, black (Salvia mellifera)	I
286	Currant, western black (R. petiolare)	S	329	Sage, purple (S. leucophylla)	I
287	Dewberry (R. villosus)	I	330	Sage, white (S. apiana)	I
288	Dogwood (Cornus spp)	S	331	Sagebrush, big (Artemisia tridentata)	S, I
289	Elderberry (Sambucus canadensis, Sambucus spp)	S	332	Sagebrush, black (A. nova)	S
290	Elder, box (Acer negundo)	S, I	333	Sagebrush, California or coastal (A. californica)	S
291	Elm (Ulmus spp)	S, I	334	Saltbush (Atriplex spp)	S
292	Fern, sweet (Myrica asplenifolia, Comptonia perigrina)	S, R	335	Sassafras (Sassafras albidum)	S
293	Gooseberries, gummy (Ribes lobii)	S	336	Silverberry (Elaeagnus commutata)	S, I
294	Gooseberries, Sierra (R. roezlii)	S	337	Spicebush (Benzoin aestivale)	S
295	Gooseberries, Siskiyou (R. binominatum)	S	338	Sumac, poison, staghorn and others (Rhus spp)	S
296	Gooseberries, white-stemmed (R. inerme)	S, I	339	Sycamore (Plantanus occidentalis)	S
297	Grape, wild and cultivated (Vitis spp)	S	340	Tamarisk (Tamarix spp)	I
298	Gum, sweet (Liquidambar styraciflua)	S, I	341	Tobacco, tree (Nicotiana glauca)	S
299	Gum, tupelo or black (Nyssa sylvatica)	S	342	Tree-of-heaven (Ailanthus glandulosa)	S, I
300	Hardhack (Spiraea spp)	I	343	Viburnum (Viburnum spp)	I
301	Hawthorn [thornapple] (Crataegus spp)	S, R	344	Walnut, black (Juglans nigra)	I
			345	Walnut, white (J. cinerea)	S
			346	Willow, species highly variable (Salix spp)	S, I

/1/ Resistant species. Annual and winter annual weeds: Buckwheat, tartary (Fagopyrum tataricum); bur, buffalo (Solanum rostratum); catchfly, night-flowering and others (Silene noctiflora, Silene spp); chess (Bromus secalinus); crabgrass (Digitaria sanguinalis); foxtail, green (Setaria viridis); grasses, all weedy annual species; hemp-nettle (Galeopsis tetrahit); oats, wild (Avena fatua); sorrel, wood (Oxalis spp); spurrey, corn (Spergula arvensis). Herbaceous biennial and perennial weeds: beardtongue (Penstemon laevigatus); bittersweet [climbing nightshade] (Solanum dulcamara); bracken (Pteris aquilina, Pteridium aquilinum); cactus, prickly pear (Opuntia spp); campion, bladder (Silene latifolia, S. cucubalus); catchfly, night-blooming (S. noctiflora); cinquefoil, shrubby (Potentilla fruticosa); cockle, white (Lychnis alba); danthonia, timber (Danthonia intermedia); dog-bane, spreading (Apocynum androsaemifolium); ferns, many kinds; goutweed (Aegopodium podagraria); grasses, all species; harebell [bellflower] (Campanula spp); knotweed [smartweed] (Polygonum spp); larkspur, tall (Delphinium occidentale); mallow, alkali [white malva] (Sida hederacea); milkweed, climbing (Gonolobus laevis, G. gonocarpus); milkweed (Asclepias spp, A. sinica); milkweed, showy (A. speciosa); nettle, horse (Solanum carolinense); quackgrass [twitch grass] (Agropyron repens); sedges (Carex spp); sorrel, wood or red ox (Oxalis spp); spurge, cypress (Euphorbia cyparissias); spurge, snow-on-the-mountain (E. marginata); strawberry, wild (Fragaria spp); tansy (Tanacetum vulgare); tick-trefoil (Desmodium spp); toadflax (Linaria vulgaris); whitetop, globe-podded (Cardaria pubescens). Woody plants: apple, common (Pyrus malus); aborvitae [white cedar] (Thuja occidentalis); ash, green (Fraxinus pennsylvanica); ash, white (F. americana); beech (Fagus spp); buckthorn, common or European (Rhamnus cathartica); cedar, dryland (Juniperus pinchota); cedar, red (J. virginiana); chokeberry (Aronia melanocarpa); elm, red (Ulmus fulva); hackberry (Celtis occidentalis); hemlock (Tsuga spp); locust, honey (Gleditsia triacanthos); mahonia (Mahonia repens); meadowsweet (Spiraea latifolia); mesquite, velvet (Prosopis juliflora var. velutina); orange, osage ["hedge," hedgeapple] (Maclura pomifera); pines (Pinus spp); rabbitbrush, small (Chrysothamnus stenophyllus); raspberry, wild [black and red] (Rubus spp); rhododendron (Rhododendron canadense); rose, wild [species variable, mostly resistant] (Rosa spp); spruces (Picea spp).

341. GROWTH REGULATORS PROMOTING CELL ELONGATION, RELATIVE ACTIVITY: PLANTS

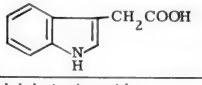
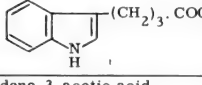
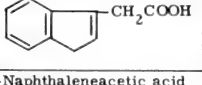
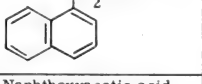
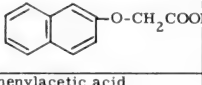
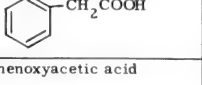
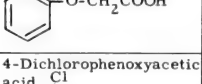
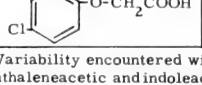
The elongation effect is determined by floating 15 apical sections (3mm in length) of decapitated *Avena* coleoptiles, 90-92 hours old, on the surface of 25 ml of solution in a covered Petri dish at 24°C for 24 hours. Where concentrations greater than 10^{-5} M are required for an elongation of 0.15 mm, the pH of the solutions is adjusted to 5.6 with NaOH.

Activity Index = $\frac{\text{molar concentration of indole-3-acetic acid inducing an elongation of 0.15mm} \times 100}{\text{molar concentration of growth regulator inducing an elongation of 0.15 mm}}$

Compound	Activity Index	Compound	Activity Index	Compound	Activity Index
1 Indole-3-acetic acid (5×10^{-8} M)	100	28 m-Trifluoromethylphenoxyacetic acid	7	59 Benzoic acid	Inactive
2 Indole-3-acetonitrile	250	29 o-Iodophenoxyacetic acid	0.1	60 o-Aminobenzoic acid	Inactive
3 4-Chloroindole-3-acetic acid	140	30 p-Iodophenoxyacetic acid	Inactive	61 o-Bromobenzoic acid	0.1
4 2-Methylindole-3-acetic acid	1.5	31 2,4-Diiodophenoxyacetic acid	Inactive	62 m-Bromobenzoic acid	Inactive
5 4,7-Dichloro-2-methylindole-3-acetic acid	0.1	32 o-Methoxyphenoxyacetic acid	Inactive	63 p-Bromobenzoic acid	Inactive
6 5,7-Dichloro-2-methylindole-3-acetic acid	1.5	33 m-Methoxyphenoxyacetic acid	0.1	64 o-Chlorobenzoic acid	0.05
7 Indole-3-butyric acid	1.5	34 p-Methoxyphenoxyacetic acid	0.03	65 m-Chlorobenzoic acid	Inactive
8 Indole-3-propionic acid	1.5	35 o-Methylphenoxyacetic acid	0.2	66 p-Chlorobenzoic acid	Inactive
9 Phenoxyacetic acid	0.03	36 m-Methylphenoxyacetic acid	0.07	67 2,4-Dichlorobenzoic acid	Inactive
10 o-Bromophenoxyacetic acid	0.1	37 p-Methylphenoxyacetic acid	0.05	68 2,5-Dichlorobenzoic acid	1
11 m-Bromophenoxyacetic acid	2.5	38 2,4-Dimethylphenoxyacetic acid	0.5	69 o-Fluorobenzoic acid	Inactive
12 p-Bromophenoxyacetic acid	1.5	39 2,5-Dimethylphenoxyacetic acid	0.2	70 Pentachlorobenzoic acid	Inactive
13 2,4-Dibromophenoxyacetic acid	12.5	40 3,5-Dimethylphenoxyacetic acid	Inactive	71 o-Iodobenzoic acid	Inactive
14 2,6-Dibromophenoxyacetic acid	Inactive	41 2,4,6-Trimethylphenoxyacetic acid	Inactive	72 2-Amino-3,5-diiodobenzoic acid	Inactive
15 2,4,6-Tribromophenoxyacetic acid	Inactive	42 o-Nitrophenoxyacetic acid	Inactive	73 2,3,5-Triiodobenzoic acid	50
16 o-Chlorophenoxyacetic acid	0.06	43 m-Nitrophenoxyacetic acid	0.2	74 3,4,5-Triiodobenzoic acid	Inactive
17 m-Chlorophenoxyacetic acid	2	44 p-Nitrophenoxyacetic acid	0.1	75 2,6-Dimethylbenzoic acid	0.05
18 p-Chlorophenoxyacetic acid	5	45 2,4-Dinitrophenoxyacetic acid	Inactive	76 2,6-Dimethyl-3-bromobenzoic acid	3
19 2,4-Dichlorophenoxyacetic acid	25	46 Phenylacetic acid	1	77 2,6-Dimethyl-3-chlorobenzoic acid	2
20 2,6-Dichlorophenoxyacetic acid	Inactive	47 α -Aminophenylacetic acid	Inactive	78 2,6-Dimethyl-3-iodobenzoic acid	2.5
21 3,5-Dichlorophenoxyacetic acid	Inactive	48 p-Aminophenylacetic acid	0.05	79 2,6-Dimethyl-3-nitrobenzoic acid	0.1
22 2,4,5-Trichlorophenoxyacetic acid	25	49 m-Fluorophenylacetic acid	1.5	80 o-Nitrobenzoic acid	0.1
23 2,4,6-Trichlorophenoxyacetic acid	Inactive	50 p-Fluorophenylacetic acid	1.5	81 Benzothiazyl-2-oxyacetic acid	0.5
24 2,4-Dichloro-6-methylphenoxyacetic acid	Inactive	51 2,5-Dihydroxyphenylacetic acid	0.02	82 α -Naphthaleneacetic acid	50
25 2,4-Dichloro-5-nitrophenoxyacetic acid	0.2	52 p-Iodophenylacetic acid	Inactive	83 β -Naphthoxyacetic acid	0.7
26 2-Ethyl-4-chlorophenoxyacetic acid	Inactive	53 2,4-Dimethylphenylacetic acid	0.5	84 2-Phenanthreneacetic acid	Inactive
27 p-Fluorophenoxyacetic acid	6	54 3,5-Dimethylphenylacetic acid	0.5	85 α -Phenoxypropionic acid	0.5
		55 2,4,6-Trimethylphenylacetic acid	Inactive	86 Phenylacetone	2
		56 p-Nitrophenylacetic acid	Inactive	87 α -Naphthaleneacetone	100
		57 p-Phenylphenylacetic acid	Inactive	88 γ -Phenylbutyric acid	1.5
		58 Diphenylacetic acid	Inactive	89 p-Chlorophenylglycine	1
				90 β -Phenylpropionic acid	Inactive

342. GROWTH REGULATORS, RELATIVE ACTIVITIES: PLANTS

Data indicate relative activity as tested by various methods. For each compound listed, as the concentration increases, the response occurs from 0 to +1, and then to a -1 when the substance becomes inhibitory. Values are applicable to the maximum positive response.

Compound	Activity Relative to Indoleacetic Acid, %					
	Avena Curvature Test	Pea Curvature Test	Rooting of Cuttings ¹	Tomato Petiole Bending	Bud Inhibition ¹	Inhibition of Root Elongation ²
1 Indoleacetic acid 	100	100	100	100	100	100
2 Indolebutyric acid 	8	190	150	6	>100	10
3 Indene-3-acetic acid 	1	20	45	14	20	
4 α -Naphthaleneacetic acid 	2.5	300	150	50	>100	4
5 β -Naphthoxyacetic acid 	0	200	25	15	100	
6 Phenylacetic acid 	0.02	10	0	0.6	0	0.3
7 Phenoxyacetic acid 	0	0	0	Trace		
8 2,4-Dichlorophenoxyacetic acid 	0	800-1200		100		30

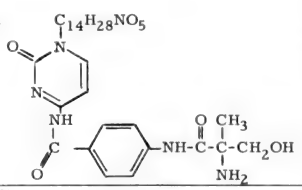
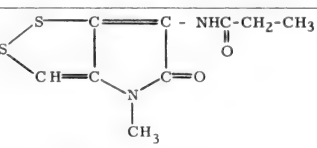
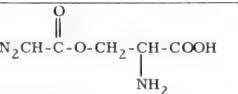
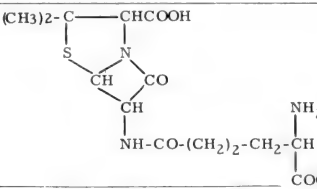
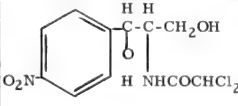
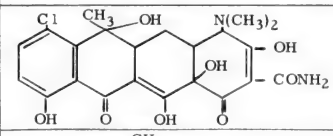
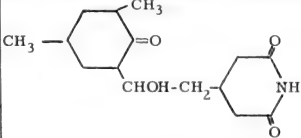
/1/ Variability encountered with species. Generally, indolebutyric acid is most effective; naphthaleneacetic and indoleacetic acids are 2nd and 3rd, respectively. /2/ In oat (*Avena sativa*).

343. GROWTH REGULATORS: APPLICATIONS AND USES

Principal Use	Chemical	Concentration Range; Treatment
1 Propagation of plants (rooting of cuttings)	Indoleacetic acid; indolebutyric acid.	1-80 mg/L H ₂ O; soak cuttings 5-24 hr.
		1-15 mg/ml of 50-95% alcohol; dip cuttings.
		1-12 mg/g; talcum powder preparation.
	α -Naphthaleneacetic acid.	1-50 mg/L H ₂ O; soak cuttings 5-24 hr.
		1-5 mg/g; talcum powder preparation.
2 Preharvest drop of fruit	Indolebutyric acid and α -naphthaleneacetic acid mixture.	1-8 mg/g (equal parts); talcum powder preparation.
	Indolebutyric acid.	1-40 mg (equal parts)/L H ₂ O; soak cuttings 5-24 hr.
	α -Naphthaleneacetic acid.	0.3 g/L; foliage spray.
	2,4-Dichlorophenoxyacetic acid (2,4-D)	10-20 ppm; water solution for apple spray.
		8-24 ppm; water solution for some varieties of apples and oranges.
3 Fruit set of tomatoes	α -(2-Chlorophenoxy)-propionic acid.	25-40 ppm; water solution sprayed on flowers and large buds.
	4-Chlorophenoxyacetic acid ¹ .	30-40 ppm; water solution sprayed on flowers and large buds.
	Naphthaleneacetic acid and derivatives ^{1,2} .	40-60 ppm; water solution sprayed on open flowers and large buds.
	Methyl ester of α -naphthaleneacetic acid.	Vapor, foliage spray.
	Acids, salts, and esters of 2,4-D.	
4 Selective weed killing		0.1-1% sprays or 1/8 lb to 3 lb per acre, or water solutions, emulsions, or various formulations depending upon purpose.
	Acids, salts, and esters of 2,4,5-trichlorophenoxyacetic acid (2,4,5-T); 2,4,5-trichlorophenoxypropionic acid.	0.1-1% sprays or 1/8 lb to 3 lb per acre, (especially used for woody plants), or water solutions, emulsions, or various formulations depending upon purpose.

/1/ Chemical modifies leaves. /2/ Esters used where vapor is necessary.

344. ANTIBIOTICS: PHYSICAL AND

	Name and Synonym	Source	Nature	Molecular Formula	Structure	Crystal Form and Color ¹	Melting Point ¹ °C
1	Actinomycin(s) ³ A ----- C	Streptomyces antibioticus, S. chrysomallus	Weakly basic chromopeptides, quinonoid	C ₄₁ H ₅₈ N ₈ O ₁₁ ----- C ₆₂ H ₈₉ N ₁₁ O ₁₇ or C ₆₀ H ₈₃ N ₁₁ O ₁₆ (?)	Unknown	Red-vermilion platelets ----- Hexagonal bipyramids, prisms or needles	250, 252 d. ----- C ₁ : 241-243 d. C ₂ : 237-239 d. C ₃ : 232-235 d.
2	Amicetin	Streptomyces vinaceus-drappus; S. fasciculatis	Amphoteric	C ₂₉ H ₄₄ N ₆ O ₉	Partial 	Hydr.: fine needles; anhy.: tan to colorless powder	Hydr.: 165-169; anhy.: 244-245; HCl: 190-192
3	Amimycin (P.A. 105)	Streptomyces antibioticus	Basic	C ₃₇ H ₆₇ NO ₁₃ ·HCl	Unknown	White crystals	Dihydr.: 134-135; HCl: 125-128
4	Amphotericin B (Fungizone)	Streptomyces spp	Amphoteric conjugated polyene	Unknown	Unknown	Clusters of long, deep yellow needles	170 d.
5	Anisomycin (Flagecidin)	Streptomyces griseolus	Basic	C ₁₄ H ₁₉ NO ₄	Unknown	Long white needles	140-141
6	Aureothricin	Streptomyces cellulosus n. spp		C ₉ H ₁₀ N ₂ O ₂ S ₂		Golden-yellow needles	256-257 d.
7	Azaserine (O-diazoacetyl-L-serine)	Streptomyces fragilis	Amphoteric	C ₅ H ₇ N ₃ O ₄		Light yellow-green needles	146-162 d. before melting
8	Bacitracin(s) ⁴ (Ayfivin)	Bacillus subtilis	Polypeptides	C ₆₅ H ₁₀₃ N ₁₇ O ₁₆ S (proposed)	Uncertain	White amorp. powder	
9	Carbomycin ⁵ (Magnamycin)	Streptomyces halstedii	Monobasic	C ₄₁ -42H ₆₇ -69NO ₁₆	Unknown	White needles or rect. plates	210-218 d.
10	Celesticetin	Streptomyces caelestis	Amphoteric	C ₂₄ H ₃₈ N ₂ O ₉ S	Unknown	Base: white glass	Salicylate: 139
11	Cephalosporin N (Synnematin B, Salmotin)	Cephalosporium sp	A hydrophilic penicillin	C ₁₄ H ₂₁ N ₃ O ₆ S		Ba salt: white powder	
12	Chloramphenicol (Chloromycetin)	Streptomyces venezuelae, S. omiyoensis	Neutral	C ₁₁ H ₁₂ N ₂ O ₅ Cl ₂		Colorless plates or fine needles	149.7-150.7 corr.
13	Chlortetracycline (Aureomycin)	Streptomyces aureofaciens	Amphoteric	C ₂₂ H ₂₃ N ₂ O ₈ Cl		Base: acicular to bladed; HCL: rhomboid, lemon-yellow	Base: 168-169 HCL: d. above 210
14	Cycloheximide (Actidione)	Streptomyces griseus	Weakly acidic	C ₁₅ H ₂₃ NO ₄		Colorless plates	119-121

/1/ a. =acid; abs. =absolute; ac. =acetic; acet. =acetone; al. =alcohol; aliph. =aliphatic; alk. =alkali(tine); amorp. =amorphous; anhy. =anhydrous; aq. =dilute; eth. =ether; filt. =filtrate; glac. =glacial; h. =hot; hex. =hexagonal; hydr. =hydrated; i. =insoluble; inact. =inactivated; lab. =labile; me.al. =prop. =propylene; pwd. =powder; pyr. =pyridine; rect. =rectangular; rm. =room; s. =soluble; sev. =several; sl. =slight; sol. =solution; solv. =solvent; were made. /3/ Other forms are: actinomycin B, C₁, C₂, C₃, D, Io, I₁, X₁, X₂. /4/ Various forms are: A, A¹, B, C, D, E, F₁, F₂, F₃, G. /5/ Carbo-

CHEMICAL CHARACTERISTICS

Optical Activity ^{1,2} [α] _D ⁺	Solubility ¹	Absorption Maxima, ¹ UV, mμ	Stability ¹	Some Other Reactions ¹	
-320 ²⁵ ± 5 in al. C ₁ : -349 ²⁰ ± 10	s. chl., bz., al., acet., 10% HCl; sl. s. w., eth.; i. pet. eth., dil. min. a., dil. alk. s. bz., chl., acet.; less s. al., glac. ac. a.	230-250, 450	Thermostable except in alk. and strong acid.	Transient purple color with conc. NaOH; neg. color with al. FeCl ₃ ; reduced by Na ₂ S ₂ O ₄ , H ₂ , over PtO to pale yellow, reversed by exposure to air. Neg. ninhydrin; gray-brown ppt. with Nessler's; yellow-green fluorescence in me. al. or glac. ac. a.	1
+116.5 ²⁴ in 0.1 N HCl	s. n-butanol saturated with w., dil. a., alk.; almost i.w., most org. solv.	305 in w. at pH 6.75; 316 in 0.1 N HCl; 322 in 0.1 N NaOH	Stable as dry solid and pH 3-5; unstable at pH > 8.	Neg. Bratton-Marshall and ninhydrin until after hydrolysis; forms sl.s. helianthate and picrate salts.	2
-54 in me. al.	Phosphate s.w.; s. methyl ethyl ketone.	286-289 (broad, low intensity maxima)	0.1% aq. sol. st. at least 24 hr pH 2.2-9.	(?)	3
+410 ²⁴ at pH 5 in dimethylformamide ¹	s. glac. ac. a.; i.w., al., acet.	225, 263, 273, 283, 345, 362, 382, 405	st. in solid form room temp.; unstable in sol.	Green color with conc. H ₂ SO ₄ ; neg. FeCl ₃ , ninhydrin, biuret, Tollen's, Fehling's; absorbs Br ₂ in glac. ac. a.	4
-30 ²³ in me. al.	s. dil. a., al., me. al., acet.; less s.w.; i. eth., CCl ₄ .	224, 277, 283, 3.34 mg in 25 ml me. al.	st. rm. temp.; therm- olab. acid pH.	Infrared: 3545, 3450, 3320, 2890, 2800, 1725, 1610, 1582, 1515, 1470 to 962 (recip. cm).	5
Inactive	sl. s. org. solv.; more s. chl.; i.w.	248, 312(?), 388	Very thermo- and acid stable.	Similar to thiolutin; acid hydrolysis yields an amine, C ₆ H ₆ N ₂ O ₂ , identical with one so obtained from thiolutin.	6
+9.7 ²⁸ in 2N HCl	s.w., h. aq. me. al., al., acet.; sl. s. abs. me. al., al., acet.	250.5 at pH 7	Acidification at pH 2 results in vigorous evolution of N ₂ and loss of biological activity.	Pronounced infrared peak at 4.66μ. Neutral solutions are stable.	7
+52 ²³ ± 2.5 in 0.02N HCl	s. al., me. al., w.; sl. s. acet., pyr., i. eth., chl., pet. eth.	A, B, D, E: 253; C, G: 250, 268; F ₁ , F ₂ , F ₃ : 253, 288	Fairly thermost., esp. at pH 4-5.	Pptd. by heavy metal salts, tannic a., conc. NaCl; pos. ninhydrin; neg. FeCl ₃ , biuret; inact. by Cu.	8
-58.6 ²⁵ in chl.	Salts: s. w., most org. solv.; base: i.w., hexane.	238, 327 in abs. al.	st. at room temp. at pH 5-7.	Neg. ninhydrin, FeCl ₃ ; pos. Fehling's, Tollen's; decolorizes Br; violet color with 40% H ₂ SO ₄ .	9
+124 ²⁴ in 1 N HCl (solv. cycle)	s. a., alk.; i. pH 7-10; salts s.w. (solv. cycle)	130.3 in 0.01 N al. KOH; 183.7 in 0.01 N H ₂ SO ₄	st. pH 5-7 at 24°C; unst. above pH 9.	Pos. FeCl ₃ , Molisch, Ekkert; neg. Benedict's, ninhydrin, iodoform.	10
Ba salt: + 187 ²⁰ in w.	i. most org. solv.; Ba salt: s.w.; sl. s. me. al.; i. al.		Unst. rm. temp. be- low pH 4 and above pH 9; inact. heavy metal ions pH 7.	Inact. by penicillinase; acid hydrolysis eventually forms a penicillamine; penicillin W is very similar in nature.	11
-25.5 ²⁵ in ethyl ace- tate; +19 ²⁵ in al.	s. al., me. al., prop. glycol; sl. s. w., chl., alk.; i. a., bz., pet. eth., veg. oils.	278	Thermostable; alk. labile.	Chlorine non-ionic; neg. FeCl ₃ , Molisch, biuret; not hydrolyzed by papain, trypsin; chymotrypsin, pepsin.	12
Base: -274.9 ²³ in me. al.; HCl: -295.9 ²³ in me. al.	Base: s. dil. a., alk., pyr.; less s. al., me. al., acet.; bz.; i. eth., pet. eth.; HCl: s. w., me. al.; sl. s. al.	HCl: 226, 264, 365 in 0.1 M H ₃ PO ₄	Thermolab. in strong a.; st. at pH 2.5; unst. at pH 7 at 25°C.	Ppts. with picric a., Reinecke's a., ammonium molybdate; UV shifts in acids, alkali; fluoresces in basic sol.	13
-2.8 ²⁵ in me. al.	s.w., all org. solv. except saturated hydrocarbons.	287	Thermostable.	Inactivated at room temp. by acetic anhydride, sodium acetate, dil. alkali.	14

aqueous; bz. =benzene; chl. =chloroform; colorl. =colorless; corr. =corrected; cryst. =crystal(line); cult. =culture; d. =decomposes; def. =definite; dil. =methyl alcohol; min. =mineral; MP = melting; MW = molecular weight; neg. =negative; org. =organic; pet. =petroleum; pos. =positive; ppt. =precipitate; st. =stable; unst. =unstable; veg. =vegetable; v. =very; w. =water; wh. =white. /2/ Superscripts in this column are temperatures at which determinations mycin B may be isomeric with carbomycin, and has the same antimicrobial spectrum.

	Name and Synonym	Source	Nature	Molecular Formula	Structure	Crystal Form and Color ¹	Melting Point ¹ °C
15	Cycloserine (Isloxazolidone, n-4-amino-3-oxamycin; Seromycin)	<i>Streptomyces garyphalus</i> , n. sp.; <i>S. orchidaceus</i> n. sp	Amphoteric	C ₃ H ₆ N ₂ O ₂		Colorless cryst.; fine white needles	154-156
16	Erythromycin (Erythrocin, Ilotycin)	<i>Streptomyces erythreus</i>	Basic	C ₃₇ H ₆₇ -69NO ₁₃ or C ₃₈ -39H ₆₉ -71NO ₁₃	Not completely determined	White needles	Base: 136-140; HCl: 170-173
17	Erythromycin C	<i>Streptomyces erythreus</i>	Basic	C ₃₆ H ₆₅ NO ₁₃	Similar to Erythromycin	Colorless needles	121-125
18	Framycetin (Actiline, Soframycine)	<i>Streptomyces</i> sp. similar to <i>S. lavendulae</i>	Basic	MW 1400-1500	Unknown	Chlorhydrate: white amorp. powder	Picrate: 189 d., corr.
19	Fumagillin (Fugillin, Ambex, Fumidil ?)	<i>Aspergillus fumigatus</i>	Weak mono-basic acid	C ₂₆ -27H ₃₄ -36O ₇		Colorless or light yellow crystals	189-194 d.
20	Glilotoxin (<i>Aspergillus</i>)	<i>Aspergillus fumigatus</i> , and several unrelated spp of fungi including <i>Trichoderma viride</i>		C ₁₃ H ₁₄ N ₂ O ₄ S ₂		Colorless plates or needles	195 d.
21	Gramicidin ⁶ (A component of tyrothricin)	<i>Bacillus brevis</i>	Neutral polypeptide	Possibly C ₁₄₈ ·H ₂₁₀ N ₃₀ O ₂₆	Unknown	Colorless platelets	228-231
22	Gramicidin S	<i>Bacillus</i> sp. similar to <i>B. brevis</i>	Cyclic decapeptide	MW 1060-1340	Uncertain	Thin colorless needles	268-270
23	Griseofulvin	<i>Penicillium griseofulvum</i> ; other <i>P.</i> spp	Neutral	C ₁₇ H ₁₇ O ₆ Cl		Colorless rhombic or octahedral crystals	218-221
24	Neomycin A ⁷ , B, C (Flavomycin)	<i>Streptomyces fradiae</i> ; other <i>S.</i> spp	Basic	A: C ₁₂ H ₂₆ N ₄ O ₆ ; B, C: C ₂₃ H ₄₈ N ₆ O ₁₃ (proposed)	Unknown	A, base: white; HCl: white amorp. pwd.	A: 256 d.
25	Novobiocin (Cathomycin)	<i>Streptomyces spheroides</i> n. sp	Acid	MW 600-618	Incomplete	Nearly colorless	Polymorphic 153; 175
26	Nystatin (Fungicidin, Mycostatin)	<i>Streptomyces noursei</i> ; <i>S. fungicidicus</i>	Amphoteric	C ₄₆ H ₇₇ NO ₁₉ (proposed)	A tetraene	Yellow needles	160+ d. with out melting at 250
27	Oxytetracycline (Terramycin)	<i>Streptomyces rimosus</i> ; <i>S. platensis</i> ; <i>S. armillatus</i>	Amphoteric	C ₂₂ H ₂₄ N ₂ O ₉		Pale yellow needles, thick hex. plates	Dihydrate: 181-182 d.; HCl: 190-194 d.
28	PA 114 A ⁸	<i>Streptomyces olivaceus</i>	Neutral	C ₂₅ H ₃₁ N ₃ O ₆ or C ₃₅ H ₄₂ N ₄ O ₉	Unknown	Colorless needles	200 d.
29	Patulin (Clavacin, Clavatin, Claviformin, Expansine, Penicidin)	<i>Penicillium</i> spp; <i>Aspergillus</i> spp	Neutral	C ₇ H ₆ O ₄		Colorless; rhomboid plates, prisms	111-112
30	Penicillic acid	<i>Penicillium</i> spp; <i>Aspergillus</i> spp; synthesis	Monobasic acid	C ₈ H ₁₀ O ₄		Colorless rhombic or hex. plates	Hydrate: 64-65; anhy. 86-87.

/1/ a.=acid; abs.=absolute; ac.=acetic; acet.=acetone; al.=alcohol; aliph.=aliphatic; alk.=alkali(ine); amorp.=amorphous; anhy.=anhydrous; aq.=aqueous; ether; filt.=filtrate; glac.=glacial; h.=hot; hex.=hexagonal; hydra.=hydrated; i.=insoluble; inact.=inactivated; lab.=labile; me. al.=methyl alcohol; min.=minimum; pyr.=pyridine; rect.=rectangular; rm.=room; s.=soluble; sev.=several; sl.=slight; sol.=solution; solv.=solvent; st.=solvent; st.=stable; /6/ Gramicidin (20%) and tyrocin (80%) are components of tyrothricin. /7/ Can be derived from B or C, and is identical with Neamine. /8/ PA

CHEMICAL CHARACTERISTICS (Continued)

Optical Activity ^{1, 2} [α] _D ²⁵	Solubility ¹	Absorption Maxima, λ UV, mμ	Stability ¹	Some Other Reactions ¹	
+116 ²⁵ in w.; +112 ²⁵ in NaOH	Dimerizes in solution.	226	Stable to alkali.	Pos. ninhydrin; $\frac{1}{2}$ of the N exists as a primary amino group; D(-)-serine and hydroxylamine isolated from hydrolyzates.	15
Base: -78 ²⁵ in al.; complex: -47 ²⁵ in al.	s.al., chl., acet.; less s.eth., w.; HCl: v.s.w., lower alcohols.	Base: 278 Complex: 274	st. at -25 to +4°C; st. 4 da at 37°C; unst. at 60-100°C.	One titratable group with pKa 8.6; activity not reduced by serum.	16
	Same as Erythromycin.	285 in me. al.	Similar to Erythromycin		17
Picrate: -32 in me. al.	Chlorhydrate: s.w., me.al.; i.acet., eth., most org.solv.		Thermostable.	No guanidinic grouping; all N as primary amine; forms picrate, reineckate; resembles streptomycin and neomycin, but differs from both.	18
-26.6 ²⁵ in me. al.	s. most org. solv., dil. alk.; i.w., dil. a.	239, 304, 322, 336, 351	Thermolabile; light sensitive.	Neg. FeCl ₃ , Millon, Fehling's, Molisch; properties change on exposure to air for one week.	19
-239 to -256 in chl.; -290±10 ²⁵ in al.	s.ac.a., acet., CCl ₄ , chl., dioxane, HCl, me.al.; sl.s.w., bz., al.	270, 450	st. to acids; unst. to alkali and light.	Readily oxidized with Br ₂ -water, forming sulfates; yields H ₂ S when reduced; black ppt. with lead acetate in boiling alkali; in alk. sol. decolorizes KMnO ₄ , giving a green color.	20
+320 in al.	s. lower alcohols, ac.a., pyr.; sl.s.abs.acet.; i.w., ether, hydrocarbons.	271, 281.5, 290.5	Thermostable.	Neg. Millon; pos. to most protein tests; hydrolyzed by acid; not digested by enzymes; forms a gel with picric acid.	21
-292 ¹⁸ in al.	s.al., chl., acet.; less s. abs.al.; i.w., a., alk.		Thermo- and acid stable.	Positive ninhydrin, biuret; neg. Millon, xanthoproteic, Pauly, Voisenet, Sakaguchi.	22
+370 ¹⁷ in chl.; +337 ²¹ in acet.	s.ac.a., dioxane, bz., eth., al., dimethyl formamide (12-14%); sl.s.chl., toluene; i.w., pet.eth.	236, 252, 291, 324	Thermostable.	Neg. FeCl ₃ , HBr, alk. Na nitroprusside, pyridine; yellow color with H ₂ SO ₄ or HNO ₃ ; reacted with phenylhydrazine, but not with diazomethane or semicarbazide. Solutions in dimethylformamide up to 1% can be diluted with H ₂ O without precipitating.	23
A. base: +112.8 ²⁵ in w.; HCl: +83 ²⁵ in w.	s.w.; sl.s.me.al.; i.other org. solv.	End absorption only.	Thermo-, acid and alkali stable.	Pos. ninhydrin, Molisch, carbazole; neg. glucosamine, Tollen's; yields furfural on acid hydrolysis; all N present as primary amino groups.	24
-63 ²⁴ in al.	s.al., me.al., acet.; i.w., chl.; Na salt s.w.	307 in 0.1N NaOH; 324 in 0.1N HCl in 90% me.al.	Thermostable.	Reacts as dibasic acid (pKa at about 4 and 9).	25
-10 ²⁵ in glac.ac.a.; +21 ²⁵ in pyr.	sl.s.al.me.al., dioxane; i.w., pyr., glac.ac.a., dimethylformamide; s.pyr.	280, 291, 304, 318	st. in cold; unst. at pH 2 or 9.	Neg. FeCl ₃ , Millon; pos. Molisch; decolorizes KMnO ₄ , Br-CCl ₄ ; in conc. H ₂ SO ₄ color change from violet to blue to black.	26
Dihydrate: -196.6 ²⁵ in 0.1N HCl; -2.125 in 0.1N NaOH	s.a., alk.; sl.s.acet., al., chl., w.; i.eth.; HCl: s.w.; i.eth., pet.eth., bz.	270, 370 in me.al. Dihydrate: 249, 276, 353 in 0.1 M KH ₂ PO ₄ , pH 4.5.	st. at acid pH; decreasingly st. at pH 7 and above at 37°C.	Pos. FeCl ₃ , Pauly, Friedel-Crafts, Fehling's Molisch; HCl pKa 3.49, 7.55, 9.24 in aq. sol., forms complexes with inorg. salts; Ba-Ca and Ba-Mg very i. in w. and ppts. readily at pH 8.5-9.5.	27
-207 in me.al.	s.al., acet., bz.; sl.s. w.; i.pet.eth.	220-230, 275	Thermostable.	Green with FeCl ₃ ; pos. copper acetate, Br ₂ in CCl ₄ .	28
Inactive	s.w., al., acet., chl.eth., dil.alk.; i.pet.eth., bz.	276	Thermostable; rather labile to alkali.	Neg. FeCl ₃ , Schiff's; red color with alk.; yellow color with dil. ammonia, asparagine, amino acids; inhibited by serum, cysteine.	29
Inactive	s.h.w., al., eth., bz., chl.; i.pet.eth.	227	Stable.	No color with FeCl ₃ in cold, orange-brown when heated; reddish-purple with strong ammonia on standing; no color with conc. H ₂ SO ₄ or NaNO ₂ .	30


bz.=benzene; chl.=chloroform; colorl.=colorless; corr.=corrected; cryst.=crystal(line); cult.=culture; d.=decomposes; def.=definite; dil.=dilute; eth.=ethyl, MP =melting point; MW =molecular weight; neg.=negative; org.=organic; pet.=petroleum; pos. positive; ppt. =precipitate; prop.=propylene; pwd.=powder; unst.=unstable; veg.=vegetable; v.=very; w.=water; wh.=white. /2/ Superscripts in this column are temperatures at which determinations were made. 114 B, with different chemical properties, is also formed during the fermentation.

	Name and Synonym	Source	Nature	Molecular Formula	Structure	Crystal Form and Color ¹	Melting Point ¹ °C
31	Penicillin(s) ⁹	Penicillium notatum, Westling; Penicillium spp; Aspergillus spp	Strong mono-basic carboxylic acids	F: C ₁₄ H ₂₀ N ₂ O ₄ S G: C ₁₆ H ₁₈ N ₂ O ₄ S K: C ₁₆ H ₂₆ N ₂ O ₄ S X: C ₁₆ H ₁₈ N ₂ O ₅ S		Colorless prisms	Na salts: F: 204-205 d. G: 215 d. X: 228-235 d.
32	Penicillin V	Penicillium chrysogenum	Acidic	C ₁₆ H ₁₈ N ₂ O ₅ S	R = (See Penicillin)	White crystals	120-128 d. (indefinite)
33	Polymyxin A, B, C, D, E (Aerosporin)	Bacillus polymyxa, various strains	Basic polypeptides	D: 4HCl: C ₅₀ H ₉₇ N ₁₅ O ₁₅ Cl ₄ B ₁ 5HCl: C ₅₆ H ₁₀₄ N ₁₆ O ₁₄ Cl ₅	Unknown	Birefringent, no definite structure	228-235 d.
34	Prodigiosin	Serratia marcescens	Red pigment; monoacidic base	C ₂₀ H ₂₅ N ₃ O		Lustrous square pyramids; dark red with a green reflex	151-152
35	Puromycin (Stylomycin)	Streptomyces alboniger; synthesis	Diacidic base	C ₂₂ H ₂₉ N ₇ O ₅		White crystals	Base: 175.5-177 (uncorr.)
36	Spiramycin (Rovamycin)	Streptomyces ambofaciens	Mixture of organic bases	C ₂₂₋₂₄ H ₃₃₋₃₄ N ₇₋₈ O	Unknown	Amorphous powder	
37	Streptolydigin	Streptomyces lydicus	Strong enol acid	C ₃₂ H ₄₅ N ₂ O ₉ Br ₃	Unknown	Orthorhombic; yellow	144-150
38	Streptomycin	Streptomyces griseus; S. bikiniensis	Strong base	C ₂₁ H ₃₉ N ₇ O ₁₂		Reineckate: thin plates; HCl: white amorp. pwd.; tri-HCl: monoclinic prisms	Reineckate: 164-165 d. Helianthate: 220-226 d.
39	Streptothricin (See Neomycin)	Streptomyces lavendulae	Basic	C ₁₃ H ₂₅ N ₅ O ₇ , or C ₂₀ H ₃₄ N ₈ O ₉ ?	Unknown	HCl and SO ₄ : wh. pwd.	Reineckate: 192-194 d.
40	Subtilin	Bacillus subtilis	Basic polypeptide	MW 3420 (found)	Unknown	Amorp. white pwd.	
41	Tetracycline (Achromycin, Panmycin, Polycycline, Steclin, Tetracyclon)	Streptomyces spp, and reductive dehalogenation of chlortetracycline	Amphoteric	C ₂₂ H ₂₄ N ₂ O ₈		Base: orthorhombic	anhyd.: 170-173 d.; HCl: 214
42	Thiolutin	Streptomyces albus	Neutral	C ₈ H ₈ N ₂ O ₂ S ₂		Yellow needles	270 d.
43	Tyrocidine ³	Bacillus brevis	Basic polypeptides	A: C ₆₆ H ₈₇ N ₁₃ O ₁₃	Uncertain	HCl: colorless needles	A: 240-242 d.
44	Viomycin (Vinactin A)	Streptomyces floridiae	Basic polypeptide	C ₁₇₋₁₈ H ₃₁₋₃₅ N ₉ O ₈	Unknown	White crystals	SO ₄ : 280 d. anhyd.: 252 d.

/1/ a.=acid; abs.=absolute; ac.=acetic; acet.=acetone; al.=alcohol; aliph.=aliphatic; alk.=alkali(ine); amorp.=amorphous; anhy.=anhydrous; aq.=aqueous; bz.=filt.; filtrate; glac.=glacial; h.=hot; hex.=hexagonal; hydr.=hydrated; i.=insoluble; inact.=inactivated; lab.=labile; me.al.=methyl alcohol; min.=powder; pyr.=pyridine; rect.=rectangular; rm.=room; s.=soluble; sev.=several; sl.=slight; sol.=solution; solv.=solvent; st.=stable; unst.=un-
/3/ Gramicidin (20%) and tyrocidine (80%) are components of tyrothricin. /9/ For penicillin F, R=CH₃-CH₂-CH=CH₂-CH₂-; for G, R=-CH₂-;

CHEMICAL CHARACTERISTICS (Concluded)

Optical Activity ^{1,2} [α] _D	Solubility ¹	Absorption Maxima, ¹ UV, mμ	Stability ¹	Some Other Reactions ¹	
F: +276-316 ²⁰⁻²⁵ in w.; G: 301-325 ²⁵ in w.; K: +258 ²⁵ ; X: +267 in w.	Acids: s.al., eth., esters; sl. s.w.; i.aliph.hydrocarb.; Na salts: s.w., al., me.al.; sl.s. ketones, ethylacetate.	G: 252, 257.5, 264 X: 278 F, K: no characteristic bands.	aq. sol. st. when pure; labile to acids, alk., heat, penicillinase.	Free acids hygroscopic, rapidly inactivated unless completely dry; inactivated by heavy metals; pptd. from sol. by aliphatic hydrocarbons; Na salts inact. in glac. ac. a., primary alcohols.	31
	s. eth., chl., al., me.al., acet.	268, 274 in water.	Free acid has much greater acid stability than other penicillins.		32
A, HCl: -422 ²⁰ in w.; B: HCl: -402 ²³ in w.	s.w., me. al.; less s. higher alcohols; i. eth., esters; base: sl. s.w.	No characteristic bands.	Thermo- and acid stable; alkali labile.	Pos. biuret, ninhydrin; neg. Molisch, Sakaguchi, Pauly; ppts. with picric, helianthic, flavianic, Reinecke acids.	33
	s.al., chl., eth., bromoform, bz.; i.w.	pH 7.4 in al., 225, 288, 337, 471, 539. pH 11 in al., 257, 281, 335, 468. pH 2.9 in al., 216, 296, 371, 541.	Thermostable.	Forms picrate, MP 176°C; salicylate, MP 178°C; benzoate, MP 170°C; perchlorate, MP 228°C (uncorr.).	34
-11 ²⁵ in al.	HCl: s. lower alcohols, w.; sl.s. ethyl acetate; i. pet. eth., chl.; Base: s.aq. alcohols; i.w., eth., pet. eth.	275 in 0.1 N NaOH; 267.5 in 0.1 N HCl	Thermo- and pH stable.	Readily forms a dihydrochloride or monosulfate; neg. Brady's; infrared: 3309, 3200, 3125, 1645, 1600, 1560, 1512, 1428, 1403, 1345, 1303, 1248, 1230, 1184, 1158, 1107, 1070, 1040, 998, 968, 930, 871, 820, 791, 758 (recip. cm).	35
	sl.s.w.; s. most org. solv.	231-232		Silicotungstic acid → white ppt.; picric acid → yellow ppt.	36
-65.7 ²⁵ in al. KOH	s. most org. solv.; i.w.; Na and K salts s.w.	262, 291, 335 in al. KOH; 357.370 in al. H ₂ SO ₄	Stable alk.; labile acid.	Pos. FeCl ₃ , iodoform; neg. Fehling's, Molisch, biuret, ninhydrin.	37
HCl: -84 in w.; SO ₄ : -79 ²⁵ in w.; tri-HCl: -86.1 ^{26.6} in w.	s.w.; less s. lower alcohols; i. other org. solv.	End absorption only.	Stable pH 3-7; less stable to heat, acid, alkali.	Maltol produced by alk. hydrolysis; inactivated by cysteine, reactivated by iodine; acid hydrolysis yields streptidine, streptobiosamine; pos. Sakaguchi; reacts rapidly with carbonyl group reagents.	38
-51.3 ²⁵ in w.	HCl: s.w., dil. mineral a.; i. eth., pet. eth., chl.	End absorption only.	st. pH 1-8.5; thermolab. in cult. filt.	Pos. biuret, ninhydrin, Pauly; neg. FeCl ₃ , Molisch, Sakaguchi, Schiff's, Millon.	39
-29 to 35 ²³ in ac. a.	s.w., me.al., ac.a.; i. anhyd.al., acet., eth., chl.		Stable, esp. at pH 2.5.	Inact. by light, trypsin, me. al.; blue with FeCl ₃ ; dialyzable.	40
-239 ²⁵ in me. al.; -257.9 ²⁵ in 0.1 N HCl	Trihydrate: sl. s.w.; HCl: s.w.	220, 268, 355 in 0.1 N HCl; 268, 363 in 0.01 M me. HCl. 246, 372 in 0.01 M me. NaOH.	st. in sol. at pH 7.0; 50% loss in 12 hr at pH 8.85; no loss in 0.1 N H ₂ SO ₄ 48 hr.	pKa 8.3, 10.2 in 50% aq. dimethylformamide; orange-yellow color with Ehrlich's in dil. HCl; chlortetracycline dehalogenated in presence of palladium yields tetracycline.	41
Inactive	s. most org. solv.; sl. s.w.	250, 311, 388 in me. al.	Acid stable; alkali labile.	Raney nickel treatment yields "desthiolutin" (MP 130-131°C); acid hydrolysis yields an amine, C ₆ H ₆ N ₂ OS ₂ (see aureothricin).	42
A: -101 ²⁵ in al.	s. al., me. al., ac.a.; sl. s.w., acet.; i. eth., chl.	A: 290	Thermostable.	Pos. ninhydrin, Millon; red color with diazobenzenesulfonic acid; not digested by enzymes.	43
SO ₄ : -32 in w.	SO ₄ and HCl: s.w.; i. most org. solv.	268 in 0.1 N HCl; 282.5 in 0.1 N NaOH 268.5 at pH 7	Very st. in acid; less st. in alk.	Pos. Sakaguchi, biuret, Fehling's, ninhydrin; neg. maltol, Molisch, Benedict's.	44

benzene; chl.=chloroform; colorl.=colorless; corr.=corrected; cryst.=crystal(line); cult.=culture; d.=decomposes; def.=definite; dil.=dilute; eth.=ether; mineral; MP=melting point; MW=molecular weight; neg.=negative; org.=organic; pet.=petroleum; pos.=positive; ppt.=precipitate; prop.=propylene; pwd.=stable; veg.=vegetable; v.=very; w.=water; wh.=white. /2/ Superscripts in this column are temperatures at which determinations were made.
for K, R=CH₃(CH₂)₆-; and for X, R=HO--CH₂-

345. ANTIBIOTICS: BIOLOGICAL CHARACTERISTICS

- 1 **ACTINOMYCIN(S)**: IN VITRO: Inhibit some Gram-pos. and Gram-neg. bacteria, and certain fungi. IN VIVO: A inactive against *Diplococcus pneumoniae* and *Streptococcus pyogenes* infections in mice. Actinomycin C shows cytostatic activity against malignant tumors: Crocker sarcoma 180, Walker-carcinoma, mouse RC carcinoma. CLINICAL: C gave encouraging results in a few patients with lymphogranulomatosis. Inconclusive results in patients with a variety of inoperable malignant conditions.
- 2 **AMICETIN**: IN VITRO: Active against mycobacteria and Gram-pos. bacteria. IN VIVO: Active against *Mycobacterium tuberculosis* H37Rv in infected mice and against certain animal tumors. CLINICAL: Preliminary studies indicate that it is well tolerated in man when administered intramuscularly or intravenously.
- 3 **AMIMYCIN**: IN VITRO: Active against Gram-pos. bacteria, including mycobacteria. Active against some Gram-neg. bacteria (*Hemophilus*, *Neisseria* and *Brucella*), rickettsiae, large viruses and protozoa. CLINICAL: Effective in bacterial pneumonia and staphylococcal enteritis, especially in types resistant to other antibiotics. No serious side effects reported.
- 4 **AMPHOTERICINS A and B**: IN VITRO: Inhibits many pathogenic and saprophytic fungi. IN VIVO: B protected mice against systemic infection by *Candida albicans*, *Histoplasma capsulatum*, and *Cryptococcus neoformans*. Active against topical infection by *Trichophyton mentagrophytes* in mice. Protects guinea pigs from *Entamoeba histolytica* infection. CLINICAL: Favorable results vs *Tr. vaginalis*.
- 5 **ANISOMYCIN**: IN VITRO: Little or no antibacterial activity. Inhibits certain fungi, protozoa. IN VIVO: Active in *Trichomonas foetus* infection in mice. Protects guinea pigs from *Entamoeba histolytica* infection. CLINICAL: Favorable results vs *Tr. vaginalis*.
- 6 **AUREOTHROCIN**: IN VITRO: Active against Gram-pos. and Gram-neg. bacteria, mycobacteria and fungi. IN VIVO: Promoted growth of chicks with low concentration in diet; diet refused with increased concentration.
- 7 **AZASERINE**: IN VITRO: Inhibits Gram-pos. and Gram-neg. bacteria, fungi and protozoa. IN VIVO: Active against *Plasmodium lophurae* in chicks, meningopneumonitis virus and *Rickettsia prowazekii* in chick embryos. Cytostatic activity against mouse leukemia, Crocker mouse sarcoma, carcinomas. No protection against *Mycobacterium tuberculosis* or viruses.
- 8 **BACITRACIN(S)**: IN VITRO: In general, active against Gram-pos. bacteria with little or no activity against Gram-neg. organisms or fungi. IN VIVO: Protects against *Clostridia*, *Micrococcus pyogenes* var. *aureus* and *Streptococcus pyogenes* infections. Active against *Borrelia duttoni* in mice, *Treponema pallidum* in rabbits. Inhibited *Plasmodium lophurae* in chicks. Active against pinworms in mice. Promotes growth in chickens, turkeys, some plants. Increases fertility and egg production in hens.
- 9 **CARBOMYCIN**: IN VITRO: Active mainly against Gram-pos. and a few Gram-neg. bacteria, large viruses, rickettsiae, and certain protozoa. IN VIVO: Good protection against *Diplococcus pneumoniae*, *Micrococcus pyogenes* var. *aureus*, *Pasteurella multocida*, *Clostridium tetani*, many rickettsiae, viruses of psittacosis, ornithosis, lymphogranuloma venereum, human and feline pneumonitis, and sporadic encephalomyelitis. Inactive against *Bacillus anthracis*, *Entamoeba histolytica*, and *Mycobacterium tuberculosis*. CLINICAL: Useful vs infections, particularly from Gram-pos. organisms resistant to penicillin and other antibiotics. Good response in *M. pyogenes* var. *aureus* and *Streptococcus pyogenes* infections; also in pneumonia caused by *D. pneumoniae* and *Str. pyogenes*. Promptly cleared lesions of *Treponema pallidum*. Good response in amebic dysentery; may be of value in granuloma inguinale.
- 10 **CELESTICETIN**: IN VITRO: Active against Gram-pos. bacteria. Only slight activity against Gram-neg. bacteria and fungi. IN VIVO: Provides complete protection vs *Streptococcus hemolyticus* and *Micrococcus aureus* in mice; increased survival time of mice infected with *Diplococcus pneumoniae* (mortality ratio unaffected). CLINICAL: Preliminary trials indicate it is well tolerated and relatively non-toxic.
- 11 **CEPHALOSPORIN N**: IN VITRO: Inhibits Gram-pos. and Gram-neg. bacteria; weakly active against *Mycobacterium tuberculosis*.
- 12 **CHLORAMPHENICOL**: IN VITRO: Active against Gram-pos. and Gram-neg. bacteria (including *Mycobacterium tuberculosis*), rickettsiae and larger viruses; no activity against fungi. Active against *Entamoeba histolytica*, *Borrelia* sp., *Trypanosoma cruzi*. IN VIVO: Protection in one or more laboratory animals against *Borrelia anserina*, *B. novyi*, *Klebsiella pneumoniae*, *Pasteurella multocida*, *Past. pestis*, *Plasmodium berghei*, *P. gallinaceum*, *Salmonella gallinarum*, *Shigella paradyseuteriae*, *Vibrio comma*, many rickettsiae, and the viruses of lymphogranuloma venereum and psittacosis. Only slight protection against *Bacillus anthracis*, *Diplococcus pneumoniae*, *Erysipelothrix rhusiopathiae*, *Listeria monocytogenes*, *Mycobacterium tuberculosis*, *Streptococcus pyogenes*, *Str. viridans* and most viruses. Showed an effect vs experimental pinworm infestation. CLINICAL: Useful in a wide variety of infections by susceptible microorganisms; especially valuable against Gram-neg. infections and the rickettsioses. Favorable results in typhoid fever, bacillary dysentery, cholera, gonorrhea, chancroid, lymphogranuloma venereum, granuloma inguinale, urinary and intestinal tract infections, bacterial pneumonia, epidemic and scrub typhus, Rocky Mt. spotted fever, Q fever, psittacosis, brucellosis, tularemia, primary atypical pneumonia, syphilis, relapsing fever, bartonellosis (Carrion's disease), non-specific urethritis, smallpox, yaws, and tropical ulcer. VETERINARY: Useful in a wide variety of infections, e.g., diarrhea of calves, colts and lambs; conjunctivitis, keratitis, and gastroenteritis in dogs. MISCELLANEOUS: Inhibited stone fruit virus in cucumber plants, and tobacco mosaic virus in tomato seedlings.
- 13 **CHLORTETRACYCLINE**: IN VITRO: Active against many Gram-pos. and Gram-neg. bacteria, rickettsiae, some viruses, and certain protozoa. Active against *Actinomyces bovis*, *Histoplasma capsulatum*. IN VIVO: Good protection in one or more laboratory animals against *Bacillus anthracis*, *Bartonella muris*, *Borrelia duttoni*, *B. novyi*, *Diplococcus pneumoniae*, *Erysipelothrix rhusiopathiae*, *Escherichia coli*, *Hemophilus influenzae*, *Klebsiella pneumoniae*, *Listeria monocytogenes*, *Pasteurella multocida*, *Plasmodium gallinaceum*, *Proteus vulgaris*, *Salmonella typhi*, *Streptococcus pyogenes*, and several spp of *Clostridium*; active in experimental leptospirosis, plague and histoplasmosis; also in most rickettsial infections, and viruses of psittacosis, Herpes zoster, rabies virus in mice, and lymphogranuloma venereum. No effect on *Mycobacterium tuberculosis*, or viruses of *H. influenzae* B, canine distemper, Newcastle disease, poliomyelitis, mumps, or foot and mouth disease. Inhibits development of Yoshida ascites in rats. CLINICAL: Good response in bacillary infections by *Aerobacter aerogenes*, *E. coli*, *Kleb. pneumoniae*, *Neisseria gonorrhoeae*, *Shigella* spp; also in chancroid, granuloma inguinale, brucellosis, tularemia, streptococcal and *D. pneumoniae* infections, and sub-acute bacterial endocarditis. Highly effective in infections by most rickettsiae and larger viruses; also in primary atypical pneumonia. Useful in amebic and urinary tract infections, and in acute bronchitis, anthrax and otitis media. As effective as penicillin in secondary syphilis, yaws, and tropical ulcer. VETERINARY: Of value in bovine infections, e.g., calf scours, pneumonia, foot rot, vibriosis, chronic bloat, heartwater and mastitis; equine infections: strangles and septicemia; swine infections: dysentery, salmonellosis, baby-pig diarrhea and pneumonia; smaller animals: leptospirosis, coccidiosis, feline distemper, fowl typhoid, and topically for skin, eye, and ear infections. RESISTANCE: A considerable number of resistant strains of *Micrococcus pyogenes* var. *aureus* have emerged; in clinical experience this has not been a problem with other bacteria, e.g., *Streptococcus* spp, *D. pneumoniae*, *Neisseria meningitidis* and *N. gonorrhoeae*. MISCELLANEOUS: Wide usage as a growth stimulant for domestic and laboratory animals. Used as preservative for fish and poultry. Effective in control of crown gall tumor of tomato and other plants, and in many bacterial diseases of plants.
- 14 **CYCLOHEXIMIDE**: IN VITRO: Little or no effect on bacteria. Affects some phytopathogenic fungi, particularly yeasts, but most fungi pathogenic to animals are not susceptible, although *Cryptococcus neoformans*, *Blastomyces dermatitidis*, and *Histoplasma capsulatum* are inhibited. Active against *Trypanosoma cruzi* and *Trichomonas* sp. IN VIVO: Effective in control of some experimental amebiasis (*Entamoeba histolytica*), meningitis. CLINICAL: Good response in a single patient with meningitis caused by *Coccidioides immitis*, and in a case of *Cryptococcus neoformans* meningitis. MISCELLANEOUS: Good control of powdery mildew and cherry leaf spot, but toxic for some plants. Effective as a rat repellent.
- 15 **CYCLOSERINE**: IN VITRO: Inhibits *Mycobacterium tuberculosis* (including strains resistant to isoniazid, pyrazinamide, and p-aminosalicylic acid); Gram-pos. and some Gram-neg. bacteria are inhibited only with high concentrations which also inhibit some fungi. IN VIVO: Relatively inactive against *Myco. tuberculosis* infection in mice; synergistic with dihydrostreptomycin. Good protection against *Diplococcus pneumoniae*, *Escherichia coli*, *Klebsiella pneumoniae*, *Micrococcus pyogenes* var. *aureus*, *Pseudomonas aeruginosa*, *Salmonella schottmuelleri*, and *Streptococcus pyogenes*. Suppressed murine typhus infection in chick embryos, and *Borrelia novyi* infection in mice. CLINICAL: Favorable responses in preliminary trials vs advanced pulmonary tuberculosis refractory to other agents. Good response in urinary infections by *Aerobacter aerogenes*, *E. coli*, *Proteus*, and *Pseudomonas*.
- 16 **ERYTHROMYCIN**: IN VITRO: Active primarily against Gram-pos. bacteria, but a few Gram-neg. organisms, certain rickettsiae and larger viruses are susceptible. Active against *Entamoeba histolytica*, *Borrelia novyi* and *Trichomonas vaginalis*. IN VIVO: Good protection against *Corynebacterium diphtheriae*, *Diplococcus pneumoniae*, *Entamoeba histolytica*, *Streptococcus pyogenes*; moderate protection against *Hemophilus pertussis*, *Micrococcus pyogenes* var. *aureus*, *Listeria monocytogenes*, *Trypanosoma equiperdum*. Not effective against *Bacillus anthracis*, *Erysipelothrix rhusiopathiae*, *Klebsiella pneumoniae*, *Salmonella gallinarum*, *Trypanosoma cruzi*, or rabies, poliomyelitis, lymphocytic choriomeningitis, influenza viruses. CLINICAL: Useful in infections by organisms resistant to penicillin and tetracycline. Highly effective in pneumococcus pneumonia and in infections by micrococci and streptococci, including pharyngitis, tonsillitis, scarlet fever and cellulitis. Favorable as well as indifferent results in gonorrhea, lymphogranuloma venereum, chancroid and donovanosis. Good responses in primary and secondary syphilis, trachoma, surgical infections and infections by *E. histolytica*. Topical therapy useful in acute pyoderma and acne vulgaris. VETERINARY: Effective in control of canine pneumonia, bronchitis, pyogenic surgical infections, otitis media and early cases of distemper. RESISTANCE: No significant cross-resistance between erythromycin and penicillin or most other antibiotics except carbomycin.

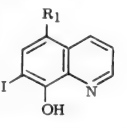
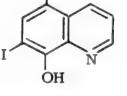
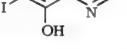
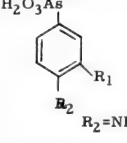
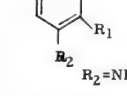
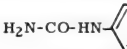
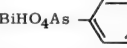
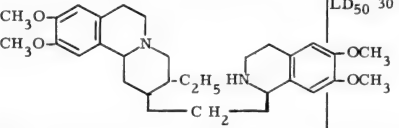
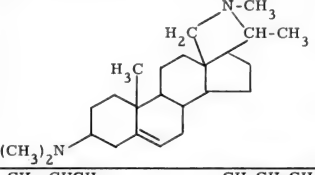
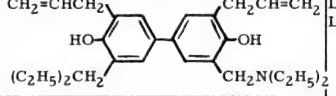
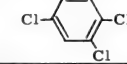
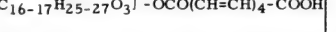
345. ANTIBIOTICS: BIOLOGICAL CHARACTERISTICS (Continued)

- 17 **ERYTHROMYCIN B**: IN VITRO: Antimicrobial spectrum similar to erythromycin.
- 18 **FRAMYCETIN**: IN VITRO: Active against Gram-pos. and Gram-neg. bacteria (including mycobacteria); low activity against fungi. CLINICAL: Topical therapy effective against staphylococcal infections.
- 19 **FUMAGILLIN**: Little or no activity against bacteria and fungi; active against certain protozoa and viruses. IN VITRO: Inhibits *Entamoeba histolytica* and *Trichomonas vaginalis*. Active against bacteriophages. In tissue cultures virucidal to eastern and western equine encephalitis, slightly active against influenza PR8, inhibits poliomyelitis (Lansing strain). IN VIVO: Highly active in experimental amebiasis; inactive against *Borrelia novyi*, *Trypanosoma cruzi*, *T. equiperdum*, and *T. gambiense*. No antiviral activity in mice with poliomyelitis (MM strain), influenza A, or swine influenza viruses. CLINICAL: Cleared majority of human *E. histolytica* cyst passers. Generally favorable results vs chronic intestinal amebiasis.
- 20 **GLIOTOXIN**: IN VITRO: Inhibits Gram-pos. and Gram-neg. bacteria and some fungi. Inactivates Gardner lymphosarcoma and various transplantable carcinomas of mice and rabbits. Sarcoma 180 implants rendered innocuous in mice. IN VIVO: No protection in mice against *Streptococcus pyogenes*, nor in experimental mouse tuberculosis. Post-treatment in mice failed to suppress implants of Sarcoma 180. MISCELLANEOUS: Good control in covered barley smut and wheat bunt; seed protective.
- 21 **GRAMICIDIN**: Primarily active against Gram-pos. bacteria. IN VITRO: Active in low concentrations against a wide variety of Gram-pos. bacteria; some Gram-neg. organisms inhibited at higher concentrations. IN VIVO: Small intraperitoneal injections gave high protection against *Bacillus anthracis*, *Clostridium perfringens*, *Diplococcus pneumoniae*, *Micrococcus pyogenes* var. *aureus* and *Plasmodium gallinaceum*. CLINICAL: Parenteral toxicity of gramicidin (or tyrothricin q.v.) precludes use in systemic infections. Topical therapy may be beneficial.
- 22 **GRAMICIDIN S**: IN VITRO: Antimicrobial spectrum similar to that of gramicidin. IN VIVO: Good protection against *Clostridium perfringens* infections. CLINICAL: Used topically in skin infections, empyema, with favorable results.
- 23 **GRISOFULVIN**: IN VITRO: Antifungal. Inhibits numerous spp. of zygomycetes, ascomycetes, basidiomycetes and fungi imperfecti. UTILIZATION: Protects plants against several phytopathogenic fungi.
- 24 **NEOMYCIN**: IN VITRO: Active primarily against Gram-pos. (including mycobacteria) and Gram-neg. bacteria and actinomycetes; little activity against fungi, viruses, or protozoa. IN VIVO: Good protection in experimental murine tuberculosis and against streptomycin-resistant strains of *Mycobacterium tuberculosis*. High protection against *Bacillus anthracis*, *Hemophilus influenzae*, *Klebsiella pneumoniae*, *Micrococcus pyogenes* var. *aureus*, *Pasteurella multocida*, *Proteus vulgaris*, *Salmonella choleraesuis*, *S. gallinarum*, *S. schottmuelleri*, *S. typhi*, *S. typhimurium*, *Vibrio comma*, and in experimental bubonic and pneumonic plague. Active against *Hemophilus pertussis* and *Salmonella pullorum* in embryonated eggs. CLINICAL: Effective pre-operative intestinal antiseptic. Of value in bacillary dysentery, amebiasis, and epidemic infantile diarrhea. Favorable results following topical therapy for many skin and ocular infections. Instillation favorable in cervicitis and vaginitis by *Proteus* spp. in non-gonococcal urethritis, peritonitis. Beneficial results in tuberculosis; nephro- and ototoxicity after prolonged parenteral administration limit usefulness. VETERINARY: A variety of gastrointestinal infections in domestic animals respond to oral therapy.
- 25 **NOVOBIOCIN**: IN VITRO: Active primarily against Gram-pos. bacteria, although a few Gram-neg. bacteria are inhibited. Active against strains resistant to commercially available antibiotics including penicillin. IN VIVO: Good protection against *Micrococcus pyogenes* var. *aureus*, *Streptococcus pyogenes*, *Diplococcus pneumoniae*, *Hemophilus pertussis*, *Proteus vulgaris*, *Pasteurella avicida*, *Neisseria meningitidis*. No protection against *Klebsiella pneumoniae*, *Escherichia coli*, *Salmonella typhi*, *S. schottmuelleri*, *Shigella dysenteriae*. No evidence of antituberculosis or antifungal activity in experimentally infected mice. No demonstrable activity against rickettsiae, viruses or protozoa in mice. Equally active orally or subcutaneously.
- 26 **FUNGICIDIN**: Active against fungi. IN VITRO: Inhibits many fungi. IN VIVO: Protects mice against *Candida albicans*, *Coccidioides immitis*, *Cryptococcus neoformans*, *Histoplasma capsulatum* and *Sporotrichum schenckii*. CLINICAL: Reduced number of *C. albicans* in fecal flora. Counteracts increase in gastrointestinal yeast flora accompanying oral tetracycline therapy. Oral doses effective against a variety of monilial infections.
- 27 **OXYTETRACYCLINE**: IN VITRO: Active against many Gram-pos. and Gram-neg. bacteria, actinomycetes, rickettsiae, larger viruses, and certain protozoa; no activity against fungi. IN VIVO: High protection in one or more laboratory animals against *Bacillus anthracis*, *Borrelia anserina*, *B. duttoni*, *B. novyi*, most *Clostridium* spp., *Diplococcus pneumoniae*, *Hemophilus influenzae*, *Klebsiella pneumoniae*, *Micrococcus pyogenes* var. *aureus*, *Pasteurella multocida*, *Past. tularensis*, *Salmonella choleraesuis*, *S. enteritidis*, *S. typhi*, *S. typhimurium*, *Streptococcus pyogenes*, and *Vibrio comma*. Active against *Bartonella muris*, *Plasmodium* spp. Suppressive effect against *Brucella melitensis*. Highly active against most rickettsiae, gray lung virus in mice and experimental feline pneumonitis virus. Effective in experimental rabbit syphilis, but less active on weight basis than penicillin. CLINICAL: Highly effective in treatment of infections by streptococci, micrococci, bacterioides, brucellae, *D. pneumoniae*, and in urinary tract infections. Useful for pre- and post-operative prophylaxis in bowel surgery, peritonitis, respiratory infections. Highly effective in most rickettsial diseases, psittacosis, lymphogranuloma venereum, granuloma inguinale and in amebic dysentery. Very effective in gonorrhea; preliminary trials in syphilis gave variable results. Favorable response in yaws, primary atypical pneumonia, *Plasmodium falciparum* malaria and *P. vivax*. Excellent response in pinworm infestation (*Enterobius vermicularis*); *Balantidium coli* infection and non-gonococcal urethritis have been treated with good results. Meningitis caused by *H. influenzae* or *Neisseria meningitidis* responded favorably. Topical therapy is effective in skin and ocular infections, including trachoma. VETERINARY: Good results vs mastitis, anaplasmosis, pneumoenteritis and metritis in cattle; necrotic enteritis in swine; chronic respiratory disease, infectious sinusitis and salmonellosis in poultry; pneumonia, wound infections, in dogs; pleuropneumonia in goats. RESISTANCE: Clinically, resistance strains of *M. pyogenes* var. *aureus* have emerged, but this has not become a problem with other bacteria. Organisms developing resistance generally exhibit cross-resistance to other tetracycline antibiotics. MISCELLANEOUS: Useful vs many bacterial diseases of plants. Growth stimulant for domestic and laboratory animals. Preservative for fish, poultry, vegetables and fruits.
- 28 **PA 114, A and B**: IN VITRO: A and B show independent activity against Gram-pos. bacteria including a wide variety of *Micrococcus pyogenes* var. *aureus* strains resistant to penicillin and other antibiotics. A and B synergize when combined in appropriate percentage combinations. IN VIVO: A and B separately showed little protection against *Streptococcus pyogenes* infections in mice. Mixtures, ranging from 1% of one to 99% of the other, showed a marked increase in activity. A partly purified product containing A and B in ratios produced during fermentation showed good protection against *Streptococcus pyogenes*, *Diplococcus pneumoniae*, and both normal and resistant strains of *Micrococcus pyogenes* var. *aureus*. No activity against yeasts or filamentous fungi. RESISTANCE: Similar to that shown by penicillin.
- 29 **PATULIN**: IN VITRO: Active against Gram-pos. and Gram-neg. bacteria, fungi. IN VIVO: Inactive against all bacteria and viruses tested. CLINICAL: Ointment of slight value in skin infections.
- 30 **PENICILLIC ACID**: IN VITRO: Active against some Gram-pos. and Gram-neg. bacteria, plant pathogens and fungi.
- 31 **PENICILLIN**: IN VITRO: In general, highly active against Gram-pos. bacteria. Although some resistant strains are encountered, most strains of the following genera are sensitive to low concentrations: *Bacillus*, *Clostridium*, *Corynebacterium*, *Diplococcus*, *Micrococcus*, *Streptococcus* and *Actinomyces*. Spp. of *Borrelia*, *Leptospira* and *Treponema* are highly sensitive. Excepting strains of *Hemophilus* and *Neisseria*, many of Gram-neg. strains are not sensitive, e.g., *Aerobacter*, *Escherichia*, *Klebsiella*, *Pasteurella*, *Proteus*, *Pseudomonas*, *Salmonella*, *Shigella* and *Vibrio* spp. Inactive against *Mycobacterium* spp., pleuropneumonia-like organisms, yeasts, fungi, viruses, rickettsiae and protozoa. IN VIVO: Activity in experimental infections similar to that of the IN VITRO antimicrobial spectrum. CLINICAL: Indicated in a wide variety of infections by susceptible organisms. Value established in veterinary practice. RESISTANCE: Has taken on proportions of a serious clinical problem only with *Micrococcus pyogenes*. The clinically isolated resistant strains are generally penicillinase producers, in contrast to the temporary resistance produced IN VITRO.
- 32 **PENICILLIN V**: IN VITRO, IN VIVO: Activity similar to that of penicillin. CLINICAL: Free acid, when given orally, yields higher blood levels than does penicillin.
- 33 **POLYMYXIN(S)**: IN VITRO: Active mainly against Gram-neg. bacteria, many of which are inhibited at low concentrations. At higher concentrations some Gram-pos. bacteria are sensitive. IN VIVO: Good protection against *Hemophilus pertussis*, *Klebsiella pneumoniae*, *Pasteurella multocida*, *Salmonella gallinarum*, *S. typhi*. CLINICAL: Promising results vs *Aerobacter aerogenes* bacteremia, pertussis, acute brucellosis, *Kleb. pneumoniae* infections. Nephro- and neurotoxicity probably caused by impurities; purified preparations of polymyxin B and E seem to be safe intramuscularly. *Pseudomonas aeruginosa* infections, especially of the urinary tract, respond to treatment with B when other antibiotics have been ineffective. Oral therapy is of value in certain gastrointestinal infections. MISCELLANEOUS: Skin histamine released at areas remote from site of subcutaneous injections of B or E in rats.
- 34 **PROMIGIOSIN**: IN VITRO: Active against certain fungi and protozoa; little or no activity against bacteria. IN VIVO: Slight activity in mice infected with *Diplococcus pneumoniae* and *Micrococcus pyogenes* var. *aureus*. Oral doses in rodents prevented *Entamoeba histolytica*, *Trypanosoma brucei* and *T. equiperdum* infections. CLINICAL: Encouraging results in a few patients having disseminated coccidioidomycosis.

345. ANTIBIOTICS: BIOLOGICAL CHARACTERISTICS (Concluded)

35. **PUROMYCIN:** IN VITRO: Active against certain Gram-pos. and Gram neg. bacteria, and protozoa. IN VIVO: Suppressed *Trypanosoma cruzi* and *T. equiperdum* infections. Good protection against *T. equinum*, *T. evansi*, *T. gambiense*, *T. rhodesiense*; little or no activity against *T. congolense*. Effective against *Entamoeba histolytica* and *Toxoplasma gondii*. Highly effective against mouse oxyurids (*Aspiculuris tetraptera* and *Syphacia obvelata*); partly suppressed tapeworm (*Hymenolepis nana* var. *fraterna*) in mice. Active against transplanted mouse mammary adenocarcinoma. Slightly effective against mouse sarcoma 180. No effect vs mouse or rat leukemia. CLINICAL: Effectively controlled *T. gambiense* and *E. histolytica* infections. Slight to moderate tumor regression in a few patients with disseminated or advanced incurable neoplastic disease.
36. **SARKOMYCIN:** IN VITRO: Inhibits *Bacillus anthracis*, *Micrococcus pyogenes* var. *aureus*, *Salmonella typhi*, *S. paratyphi*, *S. schottmuelleri*, *Proteus vulgaris*, *Pseudomonas aeruginosa*, *Mycobacterium* spp, *Nocardia asteroides*. Antifungal activity vs *Histoplasma capsulatum*, *Trichophyton mentagrophytes*, *Torula utilis*, *Cryptococcus neoformans*, *Saccharomyces sake*, *Aspergillus niger*, *Penicillium chrysogenum*. IN VIVO: Prolonged survival time in rats with Yoshida sarcoma and in mice with Ehrlich carcinoma. CLINICAL: Clinical improvement in 26 of 78 cases with inoperable carcinoma; no serious side effects observed.
37. **SPIRAMYCIN:** Principally active against Gram-pos. bacteria, particularly staphylococci resistant to the usual antibiotics. Inhibits streptococci, corynebacteria, neisseria, and certain strains of clostridia. Also active against some rickettsiae. Little activity against myco- and enteric bacteria. CLINICAL: Effective against respiratory, staphylococcal, streptococcal and gonococcal infections, virus pneumonia and exanthematic typhus.
38. **STREPTOLYDGIN:** IN VITRO: Active against Gram-pos. bacteria, particularly species of *Clostridium*, *Diplococcus*, *Streptococcus*, and *Mycobacterium*. Also active against *Pasteurella multocida*. Slight antifungal activity. IN VIVO: Effective both orally and subcutaneously in mice infected with *Streptococcus hemolyticus*, *Diplococcus pneumoniae* and *Pasteurella multocida*.
39. **STREPTOMYCIN:** IN VITRO: Active against Gram-pos. and Gram-neg. bacteria, including mycobacteria. No activity against fungi, rickettsiae, or viruses. IN VIVO: Excellent protection is afforded in a wide variety of experimental infections, including *Bacillus anthracis*, *Brucella abortus*, *Diplococcus pneumoniae*, *Micrococcus pyogenes* var. *aureus*, *Mycobacterium tuberculosis*, *Neisseria meningitidis*, *Pasteurella pestis*, *Past. tularensis*, *Streptococcus pyogenes*, and spp of *Hemophilus*, *Klebsiella*, *Pseudomonas*, *Salmonella*, *Shigella*. CLINICAL: Used with success in tuberculosis, bacteremia, meningitis, pneumonia caused by *Klebsiella pneumoniae*, empyema and other pulmonary conditions, chancreoid, tularemia, plague, skin infections by *Proteus vulgaris*, peritonitis and enteritis, corneal ulcers from *Pseudomonas aeruginosa*. RESISTANCE: Strains of Myco. tuberculosis may develop resistance very rapidly. The emergence of resistant strains of other organisms has also been noted, e.g., the majority of strains now being clinically isolated of *Aerobacter aerogenes*, *Pseudomonas aeruginosa*, *Proteus vulgaris*, and *Streptococcus fecalis* are resistant. MISCELLANEOUS: Widely used in agriculture vs several diseases including fire blights.
40. **STREPTOTHRICIN:** Active against Gram-pos. and Gram-neg. bacteria and certain fungi. IN VIVO: Active against *Brucella abortus*, *Escherichia coli*, *Pasteurella tularensis*, *Salmonella schottmuelleri*, *S. typhi*, *Shigella dysenteriae*. No protection against *Diplococcus pneumoniae*, *Pasteurella pestis*, *Proteus vulgaris*, *Pseudomonas aeruginosa*, and *Streptococcus pyogenes*. No activity in experimental tuberculosis of guinea pigs or hamsters. Suppressed *Blastomyces dermatitidis* in chick embryos. RESISTANCE: IN VITRO: Resistance develops fairly rapidly. Resistant strains frequently display cross-resistance to streptomycin and neomycin.
41. **SUBTILIN:** IN VITRO: Active mainly against Gram-pos bacteria and some fungi. Also active against bacteriophages. IN VIVO: Active experimentally against *Bacillus anthracis*, *Diplococcus pneumoniae*, *Micrococcus pyogenes* var. *aureus*, *Streptococcus pyogenes* in mice. Inactivated influenza PR8 and Newcastle disease viruses in embryonated eggs. Activity against *Rickettsia tsutsugamushi*, but less effective against *Rickettsia rickettsi* in chick embryos. MISCELLANEOUS: Used as a feed supplement for enhanced growth of chicks. May prove useful as a food preservative.
42. **TETRACYCLINE:** IN VITRO: Active against many Gram-pos and Gram-neg. bacteria, certain protozoa. IN VIVO: Good protection against *Diplococcus pneumoniae*, *Klebsiella pneumoniae*, *Micrococcus pyogenes* var. *aureus*, *Pasteurella multocida*, *Salmonella typhi*, *Streptococcus mitis*, *Str. pyogenes*. Some protection vs experimental tuberculosis in mice. Large doses suppressed *Bacillus anthracis* and *Listeria monocytogenes*, as well as virus of primary atypical pneumonia. CLINICAL: Effective in a wide variety of diseases including pneumonia, scarlet fever, otitis media, acute pharyngitis, sinusitis, osteomyelitis, laryngotracheobronchitis, meningitis, and in surgical infections and infections of the urinary tract and soft tissues. Excellent results vs acute gonorrhea. Favorable response vs non-gonococcal urethritis, acute or chronic brucellosis, lymphogranuloma venereum, donovanosis, chancreoid, psittacosis, exanthematic typhus, Rocky Mt. spotted fever, acute amebiasis, bartonellosis (Carrion's disease), and bacillary dysentery caused by *Shigella sonnei*. Successful vs a variety of skin infections, and in trachoma. Appeared to benefit 36 of 45 patients with infectious hepatitis. VETERINARY: Effective vs mastitis, shipping fever complex and pneumonia in cattle; pneumonia-enteritis complex, mastitis and listeriosis in sheep; infectious scours and pneumonia in swine; distemper in cats; pneumonia, bacillary enteritis and distemper complex in dogs; psittacosis in parakeets. RESISTANCE: IN VITRO: Resistance developed in *Escherichia coli* and *M. pyogenes* var. *aureus*; pattern similar to that of penicillin, and in contrast to that of streptomycin. Cross-resistance to other tetracyclines.
43. **THIOLUTIN:** IN VITRO: Active against some Gram-pos. and Gram-neg. bacteria, fungi, and protozoa. IN VIVO: Slight suppressive effect experimentally vs *Trypanosoma cruzi* in mice, but toxic at doses administered. No activity against *Plasmodium gallinaceum* in chicks. MISCELLANEOUS: Sprays useful in control of apple tree fire blight and late blight of potato. Controls tomato wilt by *Bacterium lycopersici*. Improved germination of oat grain infected with *Helminthosporium sativum*.
44. **TYROCIDINE:** IN VITRO: Principally inhibits Gram-pos. bacteria, some protozoa. IN VIVO: In mice, exhibits little or no effect vs *Clostridium perfringens* or *Micrococcus pyogenes* var. *aureus* infections, and no activity against *Trypanosoma cruzi*.
45. **TYROTHRIN:** IN VITRO: Active against many Gram-pos. and some Gram-neg. bacteria, certain fungi, spirochetes and protozoa. IN VIVO: In experimental infections protects against *Bacillus anthracis*, *Clostridium perfringens*, *Diplococcus pneumoniae*, *Micrococcus pyogenes* var. *aureus*, *Plasmodium gallinaceum*, *Streptococcus pyogenes*. CLINICAL: Toxicity precludes parenteral use; is ineffective orally. Used topically with success vs superficial indolent ulcers, mastoiditis, empyema, and wound infections when the predominating organisms are susceptible Gram-pos. bacteria. Effective vs tonsillitis, otitis, dermatoses, infected ulcers and burns, and infections of the eye and conjunctiva. Inhalation of an aerosol beneficial in various forms of bronchitis, in rhinopharyngitis and allergic rhinitis. Favorable results reported in treatment of puerperal mastitis by *M. pyogenes* var. *aureus*. VETERINARY: Of value vs acute and chronic mastitis in cattle, in topical treatment of infected wounds, canine dermatoses, sarcoptic mange, ear mites of dogs, cats, and rabbits, and leg mange of birds.
46. **VIOMYCIN:** IN VITRO: Inhibits some Gram-pos. and Gram-neg. bacteria and *Mycobacterium tuberculosis* (including strains resistant to streptomycin and neomycin). IN VIVO: Good protection vs Myco. tuberculosis. Strains sensitive or resistant to streptomycin equally responsive to viomycin. Protects vs *Bacillus anthracis*, *Klebsiella pneumoniae*, *Pasteurella multocida*, *Proteus vulgaris*, *Salmonella gallinarum*, *S. typhi*. Some activity vs mouse leprosy bacilli (*Mycobacterium lepraemurium*). Suppressed *Rickettsia typhi* in embryonated eggs. CLINICAL: Effective in treatment of tuberculosis, but usefulness limited as its activity is less impressive than that of streptomycin or isoniazid and because of its toxic potentialities. RESISTANCE: Myco. tuberculosis may develop resistance. Strains resistant to streptomycin or neomycin not cross-resistant to viomycin.

346. ANTIAMEBIC DRUGS: PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS

Common Name and Synonyms	Empirical Formula, Melting Point °C ¹	Solubility ¹	Structure	Acute Oral Toxicity mg/kg	Activity in vitro µg/ml	Activity against Amebiasis in Laboratory Animals		Side Effects
						Intestinal	Hepatic	
1 Diiodohydroxyquinoline (Diodoquin) ²	C ₉ H ₅ I ₂ NO MP = 200-215 d.	i. w.; sl. s. al.; eth., acet.; s. pyr., dioxane		R ₁ =I LD ₅₀ 5000 (mouse)	200-1000	Cat, dog, guinea pig, rabbit, rat.		Diarrhea.
2 Chiniofon (Yatren) ²	C ₉ H ₆ INO ₄ S MP = 244-250 d.	i. w.; al.; s. alk.		R ₁ =SO ₂ H(+Na salt) LD ₅₀ 900 (guinea pig)	100-3000	Cat, dog, guinea pig, hamster, monkey, rat.		Diarrhea, nausea and vomiting; skin rash.
3 Iodochlorohydroxyquinoline (Vioform) ²	C ₉ H ₅ ClINO MP=172 d.	i. w.; s. al.; chl., ac. a.		R ₁ =Cl LD ₅₀ 175 (guinea pig), LD ₅₀ 400 (cat)	125	Cat, dog, guinea pig, monkey, rat.		Diarrhea and abdominal pain; agranulocytosis.
4 Carbarsone ²	C ₇ H ₉ AsN ₂ O ₄	sl. s. w.; al.; i. eth., chl.; s. alk.		R ₁ =H R ₂ =NHCOCH ₃ MLD 200 (guinea pig), MLD 150 (rabbit)	125-3300	Cat, dog, guinea pig, hamster, monkey, rabbit, rat.		Arsenic reactions (rarely); diarrhea, nausea; skin rash.
5 Diaphetarsine ²	C ₁₄ H ₁₈ As ₂ N ₂ O ₆ MP=above 250	s. alk.		R ₁ =H LD ₅₀ 5000 (mouse), LD ₅₀ 2500 (rat)		Rat.		
6 Thiocarbarsone (C.C. 914)	C ₁₁ H ₁₃ AsS ₂ N ₂ O ₅ MP=83-84	sl. s. w.; s. alk.		LD ₅₀ 1000 (rat)	20-100	Monkey.	Hamster.	Gastrointestinal.
7 Bismuthoxy-glycolylarsanilate (Milibis; Glycobiarsol) ²	C ₈ H ₉ AsBiNO ₆ MP=d.	i. most solvents.		Tolerated at 10,000 (rat)	33	Cat, hamster.		Arsenic reactions (rarely); diarrhea and abdominal pain; skin rash.
8 Emetine ³	C ₂₉ H ₄₀ N ₂ O ₄ MP=233-255 (2HCl·7H2O) MP=68 MP=74 (base)	s. al., chl., eth.; sl. s. w. (base).		LD ₅₀ 30 (mouse)	0.5-31	Guinea pig, monkey, rat.	Hamster.	Diarrhea; dizziness; weakness and tenderness of skeletal muscles; damage to heart muscle.
9 Conessine (Wrightine; Neviine) ²	C ₂₄ H ₄₀ N ₂ MP=340 (2HCl) MP=125 (base) MP=222-224 (picrate)	sl. s. w.; s. acet., al.				Rat.		Central nervous system (tremors, hallucinations, nervousness).
10 Biallilylamicol (Camoform) ²	C ₂₈ H ₄₀ N ₂ O ₂ MP=210-212 (2HCl)	s. w.		LD ₅₀ 3840 (mouse), LD ₅₀ 1706 (rat)	40-134	Dog, rat.	Hamster.	Gastrointestinal; skin rash.
11 Chlorbetamide (Mantomide; Win 5047; Letrenol) ²	C ₁₁ H ₁₁ Cl ₄ NO ₂ MP=110-113	i. w., eth.; s. al.		LD ₅₀ >16,000 (mouse)	6.25-7.8	Hamster, rat, monkey.		
12 Chlortetracycline (Aureomycin) ^{2, 4}	See Table for physical and chemical properties.				29-250	Dog, guinea pig, monkey, rabbit, rat.	Hamster (slight).	Gastrointestinal; proctitis.
13 Erythromycin (Ilotycin; Erythrocin) ^{2, 4}	See Table for physical and chemical properties.				1000->1000	Monkey, rat.		Gastrointestinal.
14 Fumagillin (Fumidil) ²	C ₂₆₋₂₇ H ₃₄₋₃₆ O ₇ MP=189-194	i. w.; s. organic solvents, alk.			0.07-0.13	Dog, guinea pig, monkey, rabbit, rat.		Gastrointestinal; vertigo; leucopenia; skin rash.
15 Oxytetracycline (Terramycin) ^{2, 4}	See Table for physical and chemical properties.				133-400	Dog, guinea pig, monkey, rabbit, rat.	Hamster (slight).	Gastrointestinal; proctitis.

/1/ Abbreviations: ac.a.=acetic acid; acet.=acetone; al.=ethyl alcohol (95%); alk.=alkali; chl.=chloroform; d.=decomposes; eth.=ether; i.=insoluble; pyr.=pyridine; s.=soluble; sl.=slightly; w.=water.
 /2/ Active in intestinal amebiasis. /3/ Active in hepatic amebiasis. /4/ Probably active in an indirect manner.

347. ANTIMALARIAL DRUGS: PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS

Common Name and Synonyms	Empirical Formula, Molecular Weight, Melting Point, °C	Structural Formula	Oral Toxicity				Type of Activity							
			Mouse LD ₅₀ mg/kg	Maximum Tolerated Dose			Prophylaxis		Suppression, Active Infection		Control of Acute Attack		Eradication of Infection	
				Dog mg/kg/day	Monkey mg/kg/day	Man g/day	P. vivax ¹	P. falc. ²	P. vivax ¹	P. falc. ²	P. vivax ¹	P. falc. ²	P. vivax ¹	P. falc. ²
1 Amodiaquin (Camoquin, CAM-AQI, Miaquin, SN 10, 751)	C ₂₀ H ₂₂ ClN ₃ O MW = 355.86 MP = 208			40	25-50	0.3	-	-	++++	++++	++++	++++	-	++++
2 Chlorguanide (Guanatol, Paludrine, Palusil, Proguanil)	C ₁₁ H ₁₆ ClN ₅ MW = 253.7 MP = 135		24-70 ³	10-20	40-80	1.0	± to -	+	++	++ to ±	++	+ to ±	-	+ to ±
3 Chloroquine (Aralen, Nivaquine B, Resochin, SN 7618)	C ₁₈ H ₂₆ ClN ₃ MW = 319.88 MP = 87		752	12	25-50	0.3	-	-	++++	++++	++++	++++	-	++++
4 Pamaquine (Plasmo-chin, Plasmoquine, Praequine)	C ₁₉ H ₂₉ N ₃ O MW = 305.4 MP = 187-189 boils 0.2 mm		68	3	6	0.06 ⁴	+ to ±	+ to ±	-	-	-	-	+	-
5 Primaquine (SN 13, 272)	C ₁₅ H ₂₁ N ₃ O MW = 259.34 MP = 175-179 boils 0.2 mm		51	3	12	0.09	++ to ±	?	?	?	-	-	++	-
6 Pyrimethamine (Daraprim, BW 50-63)	C ₁₂ H ₁₃ ClN ₄ MW = 248.7 MP = 233-234		92	5± i.v. ⁵	2.5	0.025	+	++	+++	+++ to ±	++	++ to ±	+ to ±	++ to ±
7 Quinacrine (Atabrine, Atebrin, Erion, Mepacrine)	C ₂₃ H ₃₀ ClN ₃ O MW = 399.77		510-800 ⁴	40-80	50	0.2	-	-	++	++	++	++	-	++
8 Quinine	C ₂₀ H ₂₄ N ₂ O ₂ MW = 324.41 MP = 175-177		350-950 ⁴	80	480	2.0	-	-	+	+	+	+ to ±	-	+ to ±

/1/ Plasmodium vivax. /2/ Plasmodium falciparum. /3/ Range of means reported by different investigators. /4/ Three divided doses. /5/ Intravenously.

348. RODENTICIDES: PHYSICAL AND BIOLOGICAL CHARACTERISTICS

Common Name	Chemical Name	Formula	Molecular Weight	Crystalline Form, Color, Density (d)	Melting Point °C	Solubility ¹	Lethal Dose (mg/kg) ² and Relative Effectiveness ³			
							Norway Rats	Roof Rats	House Mice	Other Rodents
1 ANTU	Urea, 1-(1-naphthyl)-2-thio-	C ₁₁ H ₁₀ N ₂ S	202.27	Gray prisms from al.	198	i.w., eth.; s. h.al.	6-8 (+++) ⁴	(-)	25-130 (-)	100-400 (-)
2 Arsenic; white arsenic	Arsenic trioxide	As ₂ O ₃	197.82	White crystals or amorphous; d = 3.71.	Sublimes	sl.s.w.; s.alk., HCl, carbonates	25-100 (++ to +++) ⁵	25-100 (++ to +++) ⁵	(-)	(-)
3 Barium carbonate	Barium carbonate	BaCO ₃	197.37	White rhomboids; d = 4.43.	dec.: 1300	i.w.; s.HCl, HNO ₃ , NH ₄ Cl	750-1480 (+)	(-)	(-)	150+ (-)
4 Fumarin	Coumarin, 3-(1'-furyl-2'-acetyl)-ethyl-4-hydroxy-	C ₁₇ H ₁₄ O ₃	298	White powder.	121-123	i.w.; s.org. solv., alk.	5 ⁶ (+++)	5 ⁶ (+++)	5 ⁶ (+++)	
5 Phosphorus, yellow	Yellow phosphorus	P ₄	124.08	White or yellowish cubic or waxy solid; d = 1.82.	44.1	i.w.; s.chl., bz., CS ₂	1.7 (++)	1.7 (++)	(-)	(-)
6 Pival	1,3-Indandione, 2-pivaloyl-7	C ₁₄ H ₁₄ O ₃	230.27	Yellow needles.	108-110	i.w.; s.org. solv., alk.	5 ⁶ (+++)	5 ⁶ (+++)	5 ⁶ (+++)	
7 Red squill ⁸				Red powder.		Sl.s.w., acet., chl.; glucoside extr. by al.	400-600 (++) ⁹	(-)	(-)	(-)
8 Sodium fluoroacetate; compound 1080	Fluoroacetic acid, sodium salt	FCH ₂ COONa	100.01	White powder.	dec.: 201-204	s.w.	2-5 (+++)	2 (+++)	10 (+++)	1.4-2.2 (+++)
9 Strychnine	Strychnine	C ₂₁ H ₂₂ N ₂ O ₂	334.40	Rhombic crystals from al.	268-290	i.w.; s.chl.	16 (-)	(-)	6 (++)	(++)
10 Strychnine sulfate	Strychnine sulfate	(C ₂₁ H ₂₂ N ₂ O ₂) ₂ ·H ₂ SO ₄ ·5H ₂ O	856.97	Colorless monoclinic crystals.	dec.: 200	sl.s.2., al.; i.eth.; s.gly.	4.8 (-)	(-)	8 (++)	(++)
11 Thallium sulfate	Thallium or thallous sulfate	Tl ₂ SO ₄	504.84	White rhombic crystals; d = 6.77.	632	sl.s.c.w.; s.h.w.	16-25 (+++)	25 (+++)	25 (+++)	
12 Warfarin	Coumarin, 3-(4-acetonylbenzyl)-4-hydroxy-7	C ₁₉ H ₁₆ O ₄	308.32	Colorless needles from al.	159-161	i.w.; s.al., acet., alk.	5 ⁶ (+++)	5-20 ⁶ (+++)	5-10 ⁶ (+++)	
13 Zinc phosphide	Zinc phosphide	Zn ₃ P ₂	258.11	Dark gray cubic crystals; d = 4.55	420+	i.w.; dec. with evolution of PH ₃ in acids.	40 (++)	40 (++)	40 (++)	(++)

Common Name	Physiological Effects			Rate of Action	Relation to Man and Other Animals			
	Cumulation (Fatal)	Tolerance Developed	Cause of Death		Secondary Poisoning	Skin Absorption	Hazard in Use	Antidote ¹⁰
1 ANTU	No	Yes	Pulmonary edema; pleural effusion.	Slow.	No	No	Moderate	None.
2 Arsenic; white arsenic	No	Yes	Kidney damage; gastroenteritis; CNS affected.	Slow	No	No ¹¹	Moderate	Milk of magnesia, milk and H ₂ O, oxide of iron.
3 Barium carbonate	No	No	Intestinal spasm; digitalis-like action; CNS paralysis.	Slow.	No	No	Slight	Magnesium sulfate.
4 Fumarin	Yes	No	Blood loss from internal or external hemorrhage.	Very slow, 5-10 days exposure required.		No	Slight	Vitamin K, blood transfusions.
5 Phosphorus, yellow	No	No	Heart paralysis; liver and gastrointestinal damage.	Fast.	No	No	Moderate	Copper sulfate, followed with lavage or emetic; cathartic and water; avoid fats and oils.
6 Pival	Yes	No	Blood loss from internal or external hemorrhage.	Very slow, 5-10 days exposure required.	No	No	Slight	Vitamin K, blood transfusions.
7 Red squill ⁸	No	No	Heart and respiratory paralysis.	Slow.	No	No	Slight	Acts as emetic in animals capable of vomiting. Treat as for digitalis poisoning.
8 Sodium fluoroacetate; compound 1080	No	No	Heart and CNS paralysis.	Fast.	Yes	No ¹¹	Extreme	None reliable; monacetin or ethyl alcohol and acetic acid recommended. Rapid i.m. injection of atropine salts (3 mg) effective.
9 Strychnine	No	No	Convulsions from hyperstimulation; asphyxia.	Very fast.	No	No	Moderate	No emetic after 10 min, or after onset of convulsions; sedative, charcoal in H ₂ O, orally.
10 Strychnine sulfate								
11 Thallium sulfate	Yes	No	Gastrointestinal hemorrhage; kidney and endocrine damage; respiratory failure.	Slow.	Yes	Yes	Extreme	None reliable; sodium iodide and sodium thiosulfate may help.
12 Warfarin	Yes	No	Internal and external hemorrhage.	Very slow; 5-10 days exposure required.	See Fn 12	No	Slight	Vitamin K, blood transfusions.
13 Zinc phosphide	No	No	Heart paralysis; gastrointestinal and liver damage.	Fast.	No	No	Moderate	Copper sulfate, followed with lavage or emetic; cathartic and water; avoid fats and oils.

/1/ Abbreviations: acet. = acetone; al. = alcohol; alk. = alkali; bz. = benzene; c. = cold; chl. = chloroform; dec. = decomposes; eth. = ether; gly. = glycerine; h. = hot; i. = insoluble; org. solv. = organic solvents; s. = soluble; sl.s. = slightly soluble; w. = water. /2/ Amount necessary to control rodents under conditions of use. /3/ (-) = ineffective; (+) = poor; (++) = fair; (+++) = good. /4/ On first exposure only; ingestion of sub-lethal doses results in increased tolerance and decreased effectiveness. /5/ Lethal dose and relative effectiveness vary with particle size. /6/ Successive doses of 1 mg/kg/da required for 5 or more days. Minimum lethal dose (acute oral toxicity): fumarin 400 mg/kg; pival 200-250 mg/kg; warfarin 160 mg/kg. /7/ Alkaline salts available for use in aqueous solutions. /8/ Crude drug consists of powdered inner scales of *Urginea maritima*, with or without fortification of alcoholic extracts. Active principle appears to be one or more glucosides, one of which (scilliroside) has the formula C₃₂H₄₄O₁₂. /9/ Toxicity of crude drug may be increased through addition of alcoholic extractives, such as scilliroside. /10/ Emetics are used as first aid, except as noted. One tablespoon of salt in warm water is usually effective; physician should be called immediately. /11/ May be absorbed through cuts or breaks in the skin, also by inhalation of dusts. /12/ Reported poisonings from ingestion of warfarin-poisoned animals.

Common Name	Chemical Definition	Action
Inorganic		
1 Borax	Sodium tetraborate, $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$.	Probably slow nerve poison.
2 Calcium arsenate	Mixture of CaHAsO_4 , $\text{Ca}_5\text{H}_2(\text{AsO}_4)_4$, $\text{Ca}_3(\text{AsO}_4)_2$, $[\text{Ca}_3(\text{AsO}_4)_2]_3\text{Ca}(\text{OH})_2$, free CaCO_3 and unreacted $\text{Ca}(\text{OH})_2$.	Destroys mid-gut epithelium.
3 Calomel	Mercurous chloride, HgCl_2 .	Enzyme inhibitor.
4 Corrosive sublimate	Mercuric chloride, HgCl_2 .	Enzyme inhibitor.
5 Cryolite	Sodium aluminum fluoride, Na_3AlF_6 .	Produces flaccid paralysis.
6 Lead arsenate	Acid lead arsenate, PbHAsO_4 .	Destroys mid-gut epithelium.
7 Paris green	Copper acetoarsenite, $(\text{CuOAs}_2\text{O}_3)_3 \cdot \text{Cu}(\text{CH}_3\text{COO})_2$.	Inhibits enzymes with sulfhydryl groups.
8 Sodium arsenite	Mixture of Na_3AsO_3 and NaAsO_2 .	Destroys mid-gut epithelium.
9 Sodium fluoride	Sodium fluoride, NaF .	Nerve, stomach poison.
10 Sodium fluosilicate	Sodium silicofluoride, Na_2SiF_6 .	Nerve, stomach poison.
11 Sodium selenate	Sodium selenate, Na_2SeO_4 .	Similar to H_2S ; blocks cytochrome system (?).
12 Tartar emetic	Potassium antimonyl tartrate $\text{K}(\text{SbO})\text{C}_4\text{H}_4\text{O}_6 \cdot 1/2\text{H}_2\text{O}$.	Similar to arsenic poisoning.
13 White arsenic	Arsenious oxide, As_2O_3 .	Destroys mid-gut epithelium.
Organic		
14 Aldrin	Not less than 95% of 1, 2, 3, 4, 10, 10 -hexachloro-1, 4, 4a, 5, 8, 8a-hexahydro-1, 4-endo-exo-5, 8-dimethanonaphthalene.	Delayed action on nerve.
15 Allethrin	dl-2-Allyl-4-hydroxy-3-methyl-2-cyclopenten-1-one ester of cis- and trans-dl-chrysanthemum monocarboxylic acid.	Rapid veratrine-like nerve poison.
16 Anabesine	1-3-(2'-Piperidyl)pyridine.	Rapid nicotinic nerve poison.
17 BHC	A mixture of several isomers of 1, 2, 3, 4, 5, 6-hexachlorocyclohexane.	Potent stomach poison and persistent contact poison; fumigant.
18 Chlordane	1, 2, 4, 5, 6, 7, 8, 8-Octachloro-2, 3, 3a, 4, 7, 7a-hexahydro-4,7-methanoindene.	Delayed action on nerve.
19 Chlorthion	O, O-Dimethyl-O-(3-chloro-4-nitrophenyl) thiophosphate.	Probably anticholinesterase.
20 DDD	2, 2-bis-(p-Chlorophenyl)-1, 1-dichloroethane.	Repetitive nerve discharge.
21 DDT	2, 2-bis-(p-Chlorophenyl)-1, 1-trichloroethane.	Repetitive nerve discharge.
22 Diazinon	O, O-Diethyl-O-(2-isopropyl-4-methyl-6-pyrimidyl)thiophosphate.	Anticholinesterase (technical grade).
23 Dieldrin	Not less than 85% of 1, 2, 3, 4, 10, 10-hexachloro-6, 7-epoxy-1, 4, 4a, 5, 6, 7, 8, 8a-octahydro-1, 4-endo-exo-5, 8-dimethanonaphthalene.	Delayed action on nerve.
24 Dilan	53% 2-Nitro-1, 1-bis(p-chlorophenyl) butane and 27% 2-nitro-1, 1-bis(p-chlorophenyl) propane, and 20% related compounds.	Probably similar to DDT.
25 DNBP	4, 6-Dinitro-2-butylphenol.	Mordant stimulant nerve poison.
26 DNCHP	2, 4-Dinitro-6-cyclohexylphenol.	Mordant stimulant nerve poison.
27 DNOC	4, 6-Dinitro-o-cresol.	Mordant stimulant nerve poison.
28 Endrin	1, 2, 3, 4, 10, 10-Hexachloro-6, 7-epoxy-1, 4, 4a, 5, 6, 7, 8, 8a-octahydro-1, 4-endo-endo-5, 8-dimethanonaphthalene.	Probably like its isomer, dieldrin.
29 EPN	Ethyl-p-nitrophenylthionobenzenephosphonate.	Impure samples have anticholinesterase activity.
30 Heptachlor	1(or 3a), 4, 5, 6, 7, 8, 8-Heptachloro-3a, 4, 7, 7a-tetrahydro-4,7-methanoindene.	Delayed action on nerve.
31 Isodrin	1, 2, 3, 4, 10, 10-Hexachloro-1, 4, 4a, 5, 8, 8a-hexahydro-1, 4-endo-endo-5, 8-dimethanonaphthalene.	Delayed action on nerve, like aldrin.
32 Isopestox	bis-(Isopropylamino)fluorophosphine oxide.	Eventual anticholinesterase effect.
33 Lethane 60	Mixture of β -thiocyano ethyl esters of aliphatic fatty acids; av. C content is 10-18; $(\text{CnH}_{2n+1}\text{COOCH}_2\text{CH}_2\text{SCN})$, with 50% petroleum distillate.	Depression of respiration, rapid knockdown.
34 Lethane 384	Mixture of β -butoxy- β -thiocyanodiethyl ether with 50% petroleum distillate.	Depression of respiration, rapid knockdown.
35 Lindane	Not less than 99% of gamma isomer of 1, 2, 3, 4, 5, 6-hexachlorocyclohexane.	Rapid nerve stimulant.
36 Malathion	O, O-Dimethyl-S-(1, 2-dicarbethoxyethyl) dithiophosphate.	Anticholinesterase enzyme inhibitor.
37 Methoxychlor	1, 1, 1-Trichloro-2, 2-bis(p-methoxyphenyl)-ethane.	DDT-like action on nerve.
38 Methyl-parathion	O, O-Dimethyl-O-p-nitrophenyl thiophosphate.	Anticholinesterase.
39 Nicotine	1-3-(1-Methyl-2-pyrrolidyl)-pyridine.	Blocks ganglionic synapses.
40 Parathion	O, O-Diethyl-O-p-nitrophenyl thiophosphate.	Anticholinesterase.
41 PDB	p-Dichlorobenzene.	Stimulant, probably nervous.
42 PCP	Pentachlorophenol.	Repellent and fumigant.
43 Perthane	1, 1-bis-(p-Ethylphenyl)-2, 2-dichloroethane.	Probably similar to DDT.
44 Phenothiazine	Dibenzo-1, 4-thiazine, thiodiphenylamine.	Slow flaccid paralysis.
45 Pyrolan	Dimethyl-5-(3-methyl-1-phenyl-pyrazolol)carbamate.	Anticholinesterase.
46 Pyrethrins	Fyretrolone and cinerolone esters of chrysanthemum monocarboxylic acid and chrysanthemum dicarboxylic acid methyl ester.	Rapid veratrine-like nerve poison.
47 Rotenone	$\text{C}_{23}\text{H}_{22}\text{O}_6$.	Depresses respiration and nerve.
48 Ryania	Powdered stems of <i>R. speciosa</i> , containing active principle ryanodine ($\text{C}_{25}\text{H}_{35}\text{O}_9\text{N}$).	Ryanodine depresses muscle metabolism.
49 Sabadilla	Powdered seeds of sabadilla (<i>Schoenocaulon</i> spp), containing veratrine and veratridine.	Mild veratrine-like poison.
50 Schradan	Octamethylpyrophosphoramide.	Converted in vivo to anticholinesterase.
51 Strobane	Mixture of terpene polychlorinates containing about 66% chlorine.	
52 Systox	Mixture of O, O-diethyl-S-ethylmercaptoethyl thiophosphate and O, O-diethyl-O-ethylmercaptoethyl thiophosphate.	Probably similar to Schradan.
53 TEPP	Tetraethyl pyrophosphate, $(\text{C}_2\text{H}_5\text{O})_2\text{P}-\text{O}-\text{P}(\text{OC}_2\text{H}_5)_2$.	Anticholinesterase.
54 Thanite	Isobornyl thiocyanacetate, plus 18% terpene esters.	Quick knockdown; synergist.
55 Toxaphene	Mixture of chlorinated camphene isomers containing 67-69% chlorine.	Delayed action on nerve.

/1/ Oral, principally to albino rats, milligrams per kilogram body weight. /2/ Also *Blattella germanica*. /3/ Also *Boophilus microplus*, *Scleroracrus vaccini*, *Rhopobota naevana*, *Drosophila*. /6/ Also *Chromaphis juglandicola*.

AND BIOLOGICAL CHARACTERISTICS

Method	Insects Especially Affected	Insects Developing Tolerance	Rats LD ₅₀ ¹ mg/kg	
Inorganic				
Powders or aqueous solutions. Crop and forest dusting.	Housefly and blowfly maggot. Corn earworm, cotton leafworm.		50	1 2
Seed or seedling treatment.	Root maggot.		1-5	3
Seed or seedling treatment.	Root maggot.		1-5	4
Orchard and crop sprays and dusts.	Codling-moth, velvet bean caterpillar.	Rhagoletis completa.		5
Orchard sprays and dusts.	Codling-moth, peach moth.	Carpocapsa, Anarsia.	100	6
Sprays, dusts, baits.	Potato beetle, anopheline larva, cutworm.			7
Livestock dips, baits.	Cutworm, grasshopper.	Boophilus decoloratus, australis.	200	8
Dry powders.	Cockroach, ant, Mallophaga.		200	9
Baits, powders, impregnants.	Grasshopper, ant, clothes moth.		150	10
Systemic, by watering soil.	Aphids, scale, thrips.	Tetranychus telarius.	5	11
Bait sprays, ant traps.	Thrips, caterpillar, ant.	Scirtothrips, Taeniothrips.	6	12
Ant traps, grasshopper baits.	Ant, grasshopper.		2-85	13
Organic				
Baits, sprays, soil treatments.	Grasshopper, wireworm, ant, cutworm, root maggot, white grub.	Aedes, Culex, Musca.	50	14
Domestic aerosols, louse powders.	Housefly, louse, livestock insects.		1000	15
Contact and fumigant sprays.	Aphids.		10	16
Wettable powder, dispersible liquid or dust.	Field and garden insects, wireworm.	Musca, Boophilus decoloratus, B. microplus, Cimex, Drosophila. ²	1200	17
Dusts and residual sprays.	Cockroach, ant, mosquito, plum curculio, cotton boll weevil.	Blattella, Musca, Culex tarsalis ³	500	18
Wettable powder sprays.	Mosquito, housefly, grape berry moth.		1000	19
Orchard sprays.	Leaf-roller, corn earworm.	Musca, Aedes taeniorhynchus ⁴	2500	20
Residual sprays and dusts, paints and resin coatings, domestic aerosols.	Caterpillar, sawfly, household insects, louse, cotton boll weevil, grasshopper, Mexican bean beetle; virtually all insects except resistant species.	Musca, Aedes, Culex, Pediculus, Psychoda, Cimex, Anopheles, Carpocapsa, Boophilus, Pieris, Leptinotarsa(?), Pulex, Plutella, Blatta, Triatoma. ⁵	250	21
Wettable powder sprays.	Orchard insects, housefly.		100	22
Residual sprays.	Housefly, mosquito, ant, assassin bug, plum curculio, chinch bug, flea beetle.	Musca, Psychoda, Aedes nigromaculis, Boophilus microplus.	65-100	23
Residual emulsion sprays.	Housefly, Mexican bean beetle.	Musca.	1100	24
Dormant orchard sprays.	Aphid eggs, overwintering forms.		5-60	25
Summer orchard sprays.	Orchard mites.		30-180	26
Contact sprays and dusts.	Grasshopper, aphid eggs.		45	27
Baits and residual sprays.	Grasshopper, tobacco insects.		10	28
Orchard suspension sprays.	Aphids, psyllids, plum curculio, mosquito larva.		15-90	29
Dusts, wettable powder and emulsion sprays.	Cockroach, plum curculio, blackfly larva, cotton mite, cutworm, rootworm, wireworm.	Culex, Aedes nigromaculis	200	30
Baits and residual sprays.	Bark beetle, cutworm.		15	31
Systemic foliage sprays.	Aphids.		90	32
Aerosols and emulsion sprays.	Housefly, louse, livestock insects.		500	33
Aerosols and emulsion sprays.	Housefly, louse, livestock insects.		400	34
Contact and residual sprays, electric vaporizers, dusts.	Housefly, mosquito, louse, wireworm, household stored-products insects, orchard and field crop insects.	Musca, Blattella, Pediculus, Anopheles, Boophilus	125	35
Residual and orchard sprays, baits.	Aphids, scale, orchard mites, housefly, mosquito larva.		1250	36
Residual and livestock sprays.	Forage and truck-crop insects, Mexican bean beetle.	Musca, Pieris rapae, Drosophila.	6000+	37
Orchard sprays.	Aphids.			38
Contact sprays, fumigant vapors.	Aphids, psyllids.		10	39
Contact and residual sprays.	Aphids, most insects.	Tetranychus, Metatetranychus. ⁶	3.5	40
Fumigant of soil and closed spaces.	Clothes moth, peach borer.		2000	41
Wood impregnant.	Powder-post beetle, termite.		210	42
Wettable powder, emulsion sprays.	Leafhopper nymph, forage-crop insects.		8000	43
Oral anthelmintic.	Bot and mosquito larva.	Callitroga americana (lab.).	1500+	44
Surface sprays.	Woolly apple aphid, housefly.		60-90	45
Domestic aerosols, sprays, dusts.	Housefly, mosquito, louse, truck-crop insects, livestock insects.	Musca, Blattella.	1500	46
Crop dusts, livestock sprays.	Caterpillar, sheep-ked.	Epilachna varivestis.	25-1000	47
Dusts or wettable powders.	European corn borer, codling moth.		1200	48
Dusts.	Leafhopper, squash bug.		2000+	49
Systemic application to plants.	Aphids, scale.		20	50
Liquid insecticide.	Acarids.		250	51
Systemic application to plants.	Cotton aphid.			52
Rapid contact sprays.	Aphids, scale.	Tetranychus.	2	53
Livestock sprays and aerosols.	Housefly, horn-fly, stable-fly.		1000	54
Residual sprays and dusts.	Cotton boll weevil, cutworm, grasshopper, salt-marsh caterpillar.	Musca, Culex.	60	55

Anopheles, Psychoda. /4/ Also A. sollicitans, Pieris rapae, Drosophila. /5/ Also Erythroneura variabilis, Trichoplusia Ni., Lygus bugs, Psychoda,

350. REPRESENTATIVE ARTHROPOD REPELLENTS: CHARACTERISTICS AND EFFECTIVENESS

Values in parentheses are ranges.

	Chemical Designation	Empirical Formula	Physical Properties ^{1,2}	Solubility ¹	Anopheles quadrimaculatus		Aedes aegypti		Amblyomma americanum	Ctenocephalides felis	Trombiculid (Chigger) Mites	
					Min to 1st Bite, Skin ³	Da to 5th Bite, Cloth ³	Min to 1st Bite, Skin ³	Da to 5th Bite, Cloth ³			Min to 100% Knock-down ³	Effective after Washes no. ³
1	Benzyl benzoate (benzoic acid, benzyl ester)	C ₁₄ H ₁₂ O ₂	MW=212.24; needles, leaflets or clear oily liq.; MP=21; BP=323.4; den.=1.14 ¹⁸ ; sp gr = 1.114; n _D ²⁰ = 1.5681 ²¹	i.w.;s.acet., al., eth.	23(2-97)	<1	99(2-347)	0-5	103	197	1	3
2	Butyl acetanilide (N-butylacetanilide)	C ₁₃ H ₁₇ ON	MW=203.27; clear liq., colorl. to light straw; MP (setting point)=22; BP=277-281; sp gr=0.992 ²⁵	i.w.;s.acet., al., eth.	116(14-374)	6	218(39-481)	8-36	54-139	29	0.5	2
3	2-Butyl-2-ethyl-1,3-propanediol(1,3-propanediol, 2-butyl-2-ethyl)	C ₉ H ₂₀ O ₂	MW=160.25; wh. cr.; MP=41.4; BP=178 ⁵⁰ ; den.=0.929 ⁵⁰	0.8% s.w. at 20°C; s.acet., al., eth.	18(11-25)	<1	63(21-104)	93-196	27	<1	15+	
4	N-sec.-Butylphthalimide (phthalimide, N-sec.-butyl) ⁴	C ₁₂ H ₁₃ O ₂ N	MW=203.23; clear liq.; BP=114-116 ³ ; sp gr=1.1122 ²⁶	i.w.;s.acet., al., eth.	55(11-122)		198(11-511)	14	12	14	0.5	0
5	o-Chloro-N,N-diethylbenzamide (benzamide, o-chloro-N,N-diethyl)	C ₁₁ H ₁₄ ONCl	MW=211.69; colorl. prisms; MP=39-40; BP=125-128	i.w.;s.acet., al., eth.			470+(404-512) ⁴	1-28	8	84	1.5	0
6	Citronella, Ceylon (oils, citronella, Ceylon) ⁴		Pale, yel. liq.; sp gr=0.920 ¹⁶ ; n _D ²⁰ =1.479-1.485 ²⁰	sl.s.w.;10 vol. 80% al.	15(7-19)		74(30-148)	20-27		8	0.5	0
7	Citronella, Java (oils, citronella, Java) ⁴		Pale, yel. liq.; den.=0.885-0.900; n _D ²⁰ =1.468-1.473 ²⁰	sl.s.w., 10 vol. 80% al.	26(10-41)		114(91-157)				15+	
8	Cyclohexyl acetoacetate (acetoacetic acid, cyclohexyl ester) ⁴	C ₁₀ H ₁₆ O ₃	MW=184.23; colorl. liq.; BP=81-83 ^{0.3} ; sp gr=1.021 ²⁶ ; n _D ²⁰ =1.4590 ²⁰	i.w.;s.acet., al., eth.	57(15-226)		109(15-275)	5			15+	
9	Dibutyl adipate (adipic acid, dibutyl ester)	C ₁₄ H ₂₆ O ₄	MW=258.35; colorl. liq.; MP=-38; BP=183 ¹⁴ ; sp gr=0.965 ^{20/4}	i.w.;misc.al., eth.	21(1-61)		36(12-66)	<1	49	<1	2	3
10	Dibutyl phthalate (phthalic acid, dibutyl ester)	C ₁₆ H ₂₂ O ₄	MW=278.34; oily, colorl. liq.; BP=340; sp gr=1.045 ²¹	0.04% s.w.; v.s.al., eth., acet., bz.	18(2-84)		12(1-86)		160		12.5	3
11	Diethyl cyclohexanedicarboxylate (1,2-cyclohexane dicarboxylic acid, diethyl ester) ⁴	C ₁₂ H ₂₀ O ₄	MW=228.28; liq.; BP=83-87 ^{0.5} ; n _D ²⁰ =1.4535 ²⁵	i.w.;s.acet., al., eth.	57(15-176)		176(16-369)	27+	5		1	0
12	N,N-Diethyl-m-toluamide (tech.) (m-toluamide, N,N-diethyl)	C ₁₂ H ₁₇ ON	MW=191.26; colorl. liq.; BP=111 ¹ ; sp gr=0.9965 ²⁶ ; n _D ²⁰ =1.5206 ²⁵	i.w.;s.acet., al., eth.			812(706-840)	11-63	54	30-56 ⁵	0.2	0
13	Diisopropyl tartrate (tartaric acid, diisopropyl ester) ⁴	C ₁₀ H ₁₈ O ₆	MW=234.24; colorl. oily liq.; BP=275; sp gr=1.1171 ²⁶ ; n _D ²⁰ =1.4379 ²⁵	i.w.;s.acet., al., eth.	40(8-94)		255(7-499)	1			5.5	0
14	Dimethyl carbate (Bicyclo[2,2,1]-5-heptene-2,3-dicarboxylic acid, cis-, dimethyl ester) ⁴	C ₁₁ H ₁₄ O ₄	MW=210.22; cr. solid; MP>35 (setting point); sp gr=1.162-1.167 ^{35/4}	i.w.;misc.al.	66(9-270)	20	229(28-456)	21+	19		0.5-2.5	0
15	Dimethyl phthalate (phthalic acid, dimethyl ester) ⁴	C ₁₀ H ₁₀ O ₄	MW=194.18; clear, oily liq.; BP=282; sp gr=1.190-1.194; n _D ²⁰ =1.5154 ²¹	0.43% s.w.; s.acet., al., eth.	108(5-542) ⁺	4-21+	247(5-1051)	11-27			1-2	0
16	2-Ethoxy-N,N-diethylbenzamide (benzamide, 2-ethoxy-N,N-diethyl)	C ₁₃ H ₁₉ O ₂ N	MW=221.29; liq.; BP=115 ^{0.1} ; sp gr = 1.0294 ²⁶ ; n _D ²⁰ =1.5159 ²⁵	i.w.;s.acet., al., eth.			366(250-496)	16-63	15	92 ⁵	1.5	0
17	2-Ethyl-1,3-hexanediol (1,3-hexanediol, 2-ethyl) ⁴	C ₈ H ₁₈ O ₂	MW=146.22; clear oily liq.; BP=244.2; sp gr=0.9422 ²⁰ ; n _D ²⁰ =1.4465-1.4515 ²⁵	4.2% s.w.;s. hydrocarb.	53(2-312)	0-3	331(12-608)	27			3.5-10.5	0
18	Ethyl-β-phenylhydracrylate (hydracrylic acid, β-phenyl-ester) ⁴	C ₁₁ H ₁₄ O ₃	MW=194.22; oily liq.; BP=124-125 ¹ ; sp gr=1.0901 ²⁶ ; n _D ²⁰ =1.5082 ²²	i.w.;s.acet., al., eth.	42(19-73)		262(33-497)	36	119		0.5	0
19	Hexyl mandelate (mandelic acid, hexyl ester)	C ₁₄ H ₂₀ O ₃	MW=226.30; liq.; BP=135 ³ ; sp gr = 1.0267 ²⁶ ; n _D ²⁰ =1.4910 ²⁵	i.w.;s.acet., al., eth.	80(49-165)		279(49-502)	154	83	28	2	0
20	Indalone (2H-pyran-6-carboxylic acid, 3,4-dihydro-2,2-dimethyl-4-oxo-butyl ester) ⁴	C ₁₂ H ₁₈ O ₄	MW=226.26; light yel. liq.; BP=256-70; sp gr=1.058-1.062; n _D ²⁰ =1.4745-1.4755 ²⁵	i.w.;misc.al., chl., eth., glac.ac.a.	41(3-186)		141(24-411)	0-161	32	1	0.5-2	0
21	Navy 448 (2-cyclohexylcyclohexanol (cyclohexanol, 2-cyclohexyl))	C ₁₂ H ₂₂ O	MW=182.30; visc. liq.; BP=125-128 ⁷ ; sp gr=0.9750 ²⁶	v.sl.s.w.;s. acet., al., eth.	44(1-115)		304(2-615)	18	29		0.5	0
22	ingred- ients (cyclohexanol, 2-phenyl)	C ₁₂ H ₁₆ O	MW=176.25; light amber liq.; sp gr = 1.0450 ²⁶	v.sl.s.w.;s. acet., al., eth.	76(1-382)	1-4	368(3-1354)	27	14		0.5	0

23	Navy 448 (mixture of 30% 2-cyclohexylcyclohexanol and 70% phenylcyclohexanol)							282	18	13	8-22		
24	1,5-Pentanediol, dipropionate (propionic acid, diester with 1,5-pentanediol) ⁴	C ₁₁ H ₂₀ O ₄	MW=216.27; clear, colorl. liq.; BP=110 ² ; sp gr=0.9910 ²⁶ ; n _D =1.4274 ²⁵	i.w.;s.acet., al.,eth.	89(21-281)	160(30-304)						1-2	
25	2-Phenoxyethanol, acetate (ethanol, 2-phenoxy-, acetate) ⁴	C ₁₀ H ₁₂ O ₃	MW=180.20; liq.; BP=147-150 ²³ ; sp gr=1.1000 ²⁶ ; n _D =1.5058 ²¹	i.w.;s.acet., al.,eth.	53(6-212)	164(10-363)	8-20					0.5	0
26	Propylcinnamate (cinnamic acid; propyl ester) ⁴	C ₁₂ H ₁₄ O ₂	MW=190.23; liq.; BP=122 ¹ ; n _D =1.5467 ²⁸										
27	Propyl N,N-diethyl succinamate (succinamic acid, N,N-diethyl-, propyl ester) ⁴	C ₁₁ H ₂₁ O ₃ N	MW=215.29; clear liq.; BP=107-108 ^{0.5} ; sp gr=1.006-1.011; n _D =1.4517 ²²	i.w.;s.acet., al.,eth.	61(8-273)	322(16-494)	38	28	<1		1.5	0	
28	Thiodiethanol, diacetate (ethanol, 2,2'-thiodi-, diacetate) ⁴	C ₈ H ₁₄ O ₄ S	MW=206.26; colorl. liq.; BP=130 ⁵ ; sp gr=1.1380 ²⁶ ; n _D =1.4684 ²⁵	i.w.;s.acet., al.,eth.	47(14-328)	237(40-362)	0-63				2.5	0	
29	Undecenoic acid (undecylenic acid)	C ₁₁ H ₂₀ O ₂	MW=184.27; liq. or cr.; MP=24.5; BP=275 d.; den.=0.9102; n _D =1.4464 ²⁴	i.w.;s.al., chl.,eth.	128(8-277)	<1	168(83-460)	19+	21-123	133	2-5	0	

/1/ Abbreviations and symbols: ac.a. = acetic acid; acet. = acetone; al. = alcohol; BP = boiling point; bz. = benzene; chl. = chloroform; colorl. = colorless; cr. = crystals, crystalline; d. = decomposes; den. = density; eth. = ether; glac. = glacial; hydrocarb. = hydrocarbon; i. = insoluble; liq. = liquid; MP = melting point; misc. = miscible; MW = molecular weight; n_D = refractive index; s. = soluble; sl. = slightly; sp gr = specific gravity; v. = very; w. = water; wh. = white; yel. = yellow; visc. = viscous. /2/ MP in °C; BP in °C at atmospheric pressure (760 mm of mercury) unless otherwise indicated by specific pressure in underlined superscript; sp gr and den. at temperature (°C) indicated by underlined superscript, except in Lines 9 and 14, where temperature is referred to water at 4°C; refractive index (n_D) at temperature of °C shown in subscript. /3/ For techniques, see U.S. Department of Agriculture Handbook No. 69, "Chemicals Evaluated as Insecticides and Repellents at Orlando, Fla.," U. S. Government Printing Office, May 1954. /4/ Deemed safe for use on skin. /5/ Tests conducted with oriental rat flea (*Xenopsylla cheopis*).

351. ORGANIC INSECTICIDES: LARVICIDAL, KNOCKDOWN, AND LD₅₀ TESTS

551. ORGANIC INSECTICIDES: LARVICIDAL, KNOCKDOWN, AND LD ₅₀ TESTS																	
Insecticide		Larvicide Test Results ¹			Knockdown Test Results ²			Topical LD ₅₀ ⁵	Insecticide		Larvicide Test Results ¹			Knockdown Test Results ²			Topical LD ₅₀
		100% Effective Dose ³	Lower Doses		100% Knockdown	100% Effective for: ⁴	100% Effective Dose ³				Lower Doses		100% Knockdown	100% Effective for: ⁴			
			ppm	ppm							% kill	hr			da	μg/g		ppm	% kill	hr	da	μg/g
1	Aldrin	0.025	0.01	98	1	31+	1.6	21	Methyl parathion	0.005	0.0025	67	0.25	31+	1.0		
2	Allethrin	0.2	0.1	76	1	31+	21.5	22	Nicotine		10.0	15					
3	BHC	0.2	0.1	92	0.25	30-31		23	Para-oxon	0.025	0.01	82		31+	0.5		
4	Chlordane	0.01	0.005	52	3	31+	4.0	24	Parathion	0.0025	0.001	80	0.25	31+	0.9		
5	DDT	0.01	0.005	66	6	31+	1.65	25	PDB		10.0	70	24+	0			
6	DFDT	0.025	0.01	85	6	31+	5.0	26	Pentachloro-phenol	10.0	1.0	45	1	30-31			
7	Dieldrin	0.005	0.0025	90	3	31+	1.1	27	Phenothiazine	1.0	0.1	5	24+	0			
8	Dilan	0.1	0.05	94	24	7-8	4.75	28	Potasan	0.1	0.01	18	0.5	31+			
9	DNOC	10.0	1.0	10	1	31+		29	Pyrolan		10.0	98	1	31+			
10	DNOCHP	10.0	1.0	50	3	31+		30	Pyrethrins	0.1	0.05	78	0.25	30-31	1.0		
11	DNOSBP	10.0	1.0	0	0.25	30-31		31	Rotenone	10.0	1.0	60	24+	0			
12	Endrin		0.01	96	1	31+		32	Sabadilla				3	31+			
13	EPN	0.005	0.0025	96	24	31+	1.9	33	Schradan		10.0	42	6	31+	>500		
14	Heptachlor	0.025	0.01	79		31+	1.6	34	Sulfotepp	0.0025	0.001	74	0.5	31+	5.0		
15	Isodrin	1.0	0.1	78	3	31+		35	Systox	0.1	0.01	6	0.25	31+			
16	Lethane 60 ⁶		10.0	20	0.5	16		36	TDE	0.005	0.0025	95	6-24	0-1	6.5		
17	Lethane 384 ⁶		10.0	20	1	31+	120	37	TEPP	10.0	1.0	42	1	3-7			
18	Lindane	0.05	0.025	62	0.5	31+	1.0	38	Thanite	10.0	1.0	5	3	31+	150		
19	Malathion		0.025	96	1	31+	28	39	Toxaphene	0.01	0.005	80		31+	31.0		
20	Methoxychlor	0.1	0.05	45	24+	0	3.4										

/1/ Fourth-instar larvae (*Anopheles quadrimaculatus*) exposed 48 hr in serial water-dilutions of test compound-acetone solution. /2/ Young adults (*Pediculus humanis corporis*) exposed 24 hr on dry woolen patches previously dipped in 1% solutions of insecticides in solvent. /3/ A measure of minimum lethal concentration. /4/ A measure of residual effectiveness. /5/ *Musca domestica*. /6/ Data on per cent active ingredients not available.

352. MEDICAL FUNGICIDES: PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS

Common Name	Chemical Formula or Designation	MP °C ¹	BP °C ¹	Form, Color, Solubility ¹	Organisms Susceptible in Vitro ^{1,2,3}	Indications	Toxicity and Remarks
1 Benzoic acid	Benzene carboxylic acid.	122	249	Colorl. crys.; sl.s.w.; s. most org. solv.	Fungistatic. 2-6,8,10,11,14.	Dermatomycoses.	Used in combination with salicylic acid. Should not be used in acute phase.
2 Boric acid	H ₃ BO ₃	160	300 (-1½ HOH)	Colorl. crys. or white granules or powder; s. w., al., gly.; sl.s.acet.	Fungistatic. 1,2,4-6,9-11.	Tinea pedis, T. cruris.	Should not be used over extensive areas of unbroken skin. Poisoning from topical use has occurred in infants.
3 Caprylic acid	CH ₃ (CH ₂) ₆ COOH	16	237	Colorl. liq.; sl.s.w.; s.al., chl., eth., CS ₂ , pet.eth., glac.ac.a.	Fungistatic, weakly fungicidal. 1,2,4-6,9-14.	Dermatomycoses.	Relatively non-toxic on local application. Unpleasant odor. Only suppressive efficacy.
4 Chloramphenicol	D(-)-Threo-1-p-nitrophenyl-2-dichloroacetamido-1,3-propanediol.	150.5-151.5		Needles; sl.s.w.; s.al., acet., eth., ethyl acetate, me.alc., butyl alc., prop. glycol.	A, E, G.	Actinomycosis, cryptococcosis, nocardiosis.	Occasional blood dyscrasias. May cause candidiasis.
5 5-Chlorosalicylanilide	C ₁₃ H ₁₀ O ₂ NCl	214-216		Crys.; i.w.; sl.s.al., gly.; s.acet.	Fungistatic, weakly fungicidal. 2,4-6,9,10,12.	Tinea capitis.	About 70% effective. Occasional dermatitis, folliculitis and kerion.
6 Chlorothymol	6-Chloro-4-isopropyl-1-methyl-3-phenol.	62-64		Crys.; sl.s.w.; s.al., bz., chl., eth., pet.eth.	Fungistatic, fungicidal. 2,9-12,14.	Tinea pedis.	Primary skin irritant. Effectivity reduced in presence of serum.
7 Chlortetracycline	C ₂₂ H ₂₃ ClN ₂ O ₈	168-169		Yellow crys.; sl.s.w., alcohols, acet., bz.; s. cellosolves, dioxane, carbitol.	A, G.	Actinomycosis, nocardiosis.	Rare cases of hypersensitivity. Occasional diarrhea, skin eruptions. Candidiasis may result.
8 Diamthazole dihydrochloride	2-Dimethylamino-6-(β-diethylaminoethoxy)-benzothiazole dihydrochloride.	269		Colorl. crys.; s.w., al., me.alc.	Fungistatic, weakly fungicidal. 1,2,4-6,9-12,14.	Dermatomycoses.	Reported to cause encephalopathy in children under 5 years. Not to be used in acute stage.
9 Dibromosalicylaldehyde	3,5-Dibromo-2-hydroxybenzaldehyde.	86		Yellow prisms; sl.s.w.; s.eth., bz., chl., al., glac.ac.a.	Fungistatic, weakly fungicidal. 2,4-6,9-12,14.	Tinea capitis.	20% effective. Occasional dermatitis, folliculitis, and kerion.
10 Ethyl vanillate	3-Methoxyethyl benzoate.	44	291-293	Colorl. crys. solid; i.w.; s.al., prop. glycol, carbowax, mod. conc. cold KOH.	D, F.	Coccidioidomycosis, histoplasmosis.	Low toxicity. 30-45 g/da for 3-18 mo produces occasional nausea, acidosis, hyperpnea, or shock. Liver and kidney damage from larger doses after a month or more.
11 Gentian violet	Methyrosaniline chloride.			Green powder; s.w., al., gly., chl.; i.eth.	Fungistatic. C, 1,2,4-6,9,10,12,14.	Candidiasis, Tinea corporis, T. cruris.	Usually non-toxic topically. Stains skin and clothing. Orally may cause nausea, vomiting, diarrhea, and lassitude.
12 8-Hydroxyquinoline	8-Quinolinol	76	267	White crys.; almost i.w., eth.; s.al., acet., chl., bz.	Fungicidal, fungistatic. 1,2,9-13.	Dermatomycoses.	Occasional local allergic-type reaction.
13 Iodine tincture U.S.P.	2% iodine, 2.4% sodium iodide, alcohol.			Transparent, reddish-brown liquid.	Fungistatic. H, 1,2,4-6,9,10.	Dermatomycoses, superficial lesions in sporotrichosis.	Iodism on chronic use. Not to be used in acute phase topically.
14 Methyl paraben	Methyl parahydroxybenzoate.	125-128		Colorl. crys.; s. 1/400 w., al., eth.; sl.s.bz., CCl ₄ .	Fungistatic. C, 1.	Candidiasis.	Mixed with 4 parts propyl paraben to prevent candidiasis from antibiotic therapy. Less toxic than benzoic or salicylic acids.
15 Nystatin	Derived from cultures of Streptomyces noursei.			Yellow powder; sl.s.me. alc., prop. glycol.	Fungicidal. C, 1.	Candidiasis.	LD ₅₀ for crude nystatin i.p. in mice, 20-26 mg/kg. Too irritating for subcutaneous or intramuscular injection. Combined with antibiotics to prevent candidiasis.
16 Oxytetracycline	C ₂₂ H ₂₄ N ₂ O ₉	181-182 d.		Yellow crys. or powder; sl.s.w., al.; s.dil. HCl.	A, G.	Actinomycosis, nocardiosis.	Rare cases of hypersensitivity. Occasional diarrhea, skin eruptions. Candidiasis may result.
17 Penicillin G sodium	Benzylpenicillin sodium.			White crys.; s.al., gly.; i.acet., eth., chl.	A, E, G.	Actinomycosis, cryptococcosis, nocardiosis.	Skin rashes and eruptions, serum sickness-like symptoms, anaphylaxis, id-like reactions, mucosal lesions, other systemic reactions in sensitive people. May produce candidiasis.
18 Phenyl mercuric acetate	C ₆ H ₅ HgO ₂ C ₂ H ₃	149		White prisms; s.al., bz., 1/600 w.	Fungistatic, fungicidal. 2,4-6,9-12,14.	Dermatomycoses.	Chronic use may produce mercury poisoning. Acrodynia in children from mercury sensitization. BAL helpful as an antagonist.

19	Phenyl mercuric nitrate, N.F.	$C_6H_5HgOH \cdot C_6H_5HgNO_3$	178-184 d.		White or gray powder; sl. s.w., al.; mod.s.gly.	See phenyl mercuric acetate.		
20	Potassium iodide solution, N.F.	Saturated potassium iodide.			Clear, colorless solution.	A, B, C, D, E, H.	Actinomycosis (supplemental), candidiasis, coccidioidomycosis, cryptococcosis, N. Amer. blastomycosis.	Iodism in sensitive people. Must check for sensitivity in candidiasis, coccidioidomycosis, and N. Amer. blastomycosis as exacerbations of indolent infections have occurred.
21	Propionic acid	CH_3CH_2COOH		141	Colorl. liq.; misc. w., al., chl., eth.	Fungistatic. 1,2,4-6, 9-11, 13,14.	Dermatomycoses.	Relatively non-toxic on local application. Effect mostly suppressive.
22	Propyl paraben	Propyl parahydroxybenzoate.	95-98		Color. crys.; s. 1/2000 w., al., eth., acet.	See Methyl paraben.		
23	Salicylanilide	$C_6H_5NHCOC_6H_4OH$	134-135		White leaflets; sl.s.w.; s. al., eth., chl., bz.	Fungistatic. 2,4-6,9-11, 14.	Tinea capitis, T. favosa.	26% effective. Occasional dermatitis, folliculitis, and kerion.
24	Salicylic acid	o-Hydroxybenzoic acid.	157-159	Sublimes at 20	White crys. or powder; sl. s.w.; s.al., eth., chl.	Fungistatic. 2-6,8-11,14.	Dermatomycoses.	Irritating to skin. Keratolytic effect more pronounced than fungistatic. Used in combination with benzoic acid in Whitfield's Ointment, U.S.P.
25	Sodium iodide	NaI	651		White crys.; s.w., al., gly., acet.	See Potassium iodide.		
26	Stilbamidine	4,4'-Stilbenedicarboxamidine.	290 d.		White crys.; s.w.; sl. s. me. alc.	B, D, F.	Coccidioidomycosis, histoplasmosis, N. Amer. blastomycosis.	Local irritation, vascular reactions, kidney and liver damage, delayed facial neuropathy from trigeminal lesions.
27	Sulfadiazine	2-Sulfanilamidopyrimidine.	252-256		White or yellow powder; sl.s.w., al., acet., serum; s.dil.mineral acids, KOH, NaOH, NH_4OH .	A, E, G.	Actinomycosis, nocardiosis.	May cause contact dermatitis, crystalluria, hematuria, drug fever, renal pathology, agranulocytosis, anemia, hepatic necrosis.
28	Tetracycline	$C_{22}H_{24}N_2O_8$	170-173 d.		Yellow crys. or powder; sl.s.w.; s. al. (1:50), dil. HCl, alk. hydroxide sol.	A, G.	Actinomycosis, nocardiosis.	Rare cases of hypersensitivity. Occasional diarrhea, skin eruptions. Candidiasis.
29	Undecylenic acid	10-Undecenoic acid.	24.5	275 d.	Colorl. liq.; i.w.; s.al., chl., eth.	Fungistatic, weakly fungicidal. 1,2,4-6,9-14.	Dermatomycoses.	Usually well tolerated locally. Effect mostly suppressive.

/1/ ac. a. = acetic acid; acet. = acetone; al. = ethanol; alc. = alcohol; alk. = alkali; bz. = benzene; chl. = chloroform; colorl. = colorless; conc. = concentrated; crys. = crystals; d. = decomposes; eth. = ethyl ether; glac. = glacial; gly. = glycerol; i. = insoluble; i.p. = intraperitoneal; me. = methyl; mod. = moderately; org. solv. = organic solvents; pet. = petroleum; prop. = propylene; s. = soluble; sl. = slightly; sol. = solution(s); w. = water. /2/ Deep mycoses: A = Actinomyces bovis; B = Blastomyces dermatitidis; C = Candida albicans; D = Coccidioides immitis; E = Cryptococcus neoformans; F = Histoplasma capsulatum; G = Nocardia asteroides; H = Sporotrichum schenckii. /3/ Superficial mycoses: 1 = Candida albicans; 2 = Epidermophyton floccosum; 3 = Malassezia furfur; 4 = Microsporum audouinii; 5 = M. canis; 6 = M. gypseum; 7 = Nocardia minutissima; 8 = Trichophyton concentricum; 9 = T. mentagrophytes; 10 = T. rubrum; 11 = T. schoenleini; 12 = T. tonsurans; 13 = T. verrucosum; 14 = T. violaceum.

353. FUNGICIDES: PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS

Common Name	Chemical Name or Formula	Molecular Weight	Melting Point °C	Form and Color	Vapor Pressure mm Hg	Purity of Technical Product	Solubility ¹ g/100 g at 25°C	Toxicity Lethal Dose Rat	Relation to Human Health Skin Absorption	Degree of Hazard
1 Bordeaux mixture	Copper sulfate and lime			Blue gelatinous precipitate; crystallizes on standing.	Non-volatile		i. w.	Slightly toxic.	Poor.	Irritant. ²
2 Captan; SR-406	N-Trichloromethyl-thio-tetrahydrophthalimide	300.6	172-173 (pure) ³	Colorless crys. (pure); yellow amorphous (technical).	Non-volatile		i. w.; hydrocarbons; sl. s. al.; dioxane, chl.; s. acet., bz.	Oral LD ₅₀ 10g/kg.	Poor.	Irritant. ⁴
3 Captax	2-Mercaptobenzo-thiazole	167.2	179	White needles or leaflets.	Low; non-volatile	(?)	<0.005 w.; 19.7 acet.; 5.2 al.; 0.52 bz.; s. alk., Cellosolve.			
4 Chloranil	Tetrachloroquinone	245.9	294-295	Yellow leaflets or prisms.		(?)	<0.008 w.; 33 acet.; 16 eth.	Oral LD ₅₀ 4g/kg.	50% not toxic.	Irritant. ⁵
5 p-Chloro-m-xylene	p-Chloro-m-xylene	156	112-115.5	White to creamy white crys.	Volatile in steam.	(?)	0.0025 w.; 6.1 bz.; 86.6 al.; 50 isopropyl alc.; s. eth.		Absorbed.	
6 Compound G-4	2, 2'-Methylenebis-(4-chlorophenol)	269	179 (pure)	Almost white (pure); light pink to tan (technical).	10-10 (20°C); 10 ⁻⁴ (100°C)	High	1.7 mg/100 ml w.; 76.5 acet.; 1.4 bz.; 42.3 butanol.	Oral LD ₅₀ (?) 1g/kg.	None.	Low.
7 Copper naphthenate	Copper naphthenate	250-400		Semiviscous green fluid or green plastic mass.	0.001 (100°C)	Usually 80%	0.0015 w.; s. isopropyl alc., methyl ethyl ketone.			
8 Copper-3-phenyl-salicylate	Copper-3-phenyl-salicylate	490	148-152 d.	Tan, crystalline.	Non-volatile		i. w.; to 5% by wt. in acet., bz., linseed oil, xylene.	Oral LD ₅₀ 0.52g/kg.	None.	Low.
9 Crag 974	3, 5-Dimethyltetrahydro-1, 3, 5, 2H-thiadiazine-2-thione	152.2	100-103 d.	White crystalline powder.	1 psi absolute (30°C)	95%	0.12 w. (30°C); 19.4 acet. (30°C); 26 tri-chlorethane.	Oral LD ₅₀ 0.5g/kg.	Slight when moist.	Slight.
10 Cresatin	Metacresyl acetate	150.2	212 (boiling point)	Colorless, oily liquid.	Volatile with steam	Close to 100%	i. c. w.; s. h. w.; miscible al., eth., chl., bz., pet. eth.			
11 Dichlone; Phygon	2, 3-Dichloro-1, 4-naphthaquinone	227	193	Yellow crystalline solid.	Slightly volatile		sl. s. w.; most org. solvents, acet., dioxane.	Oral LD ₅₀ 1.5g/kg.	Poor.	Irritant.
12 Dowicide 1	o-Phenylphenol	170.2	57.2	White or light buff to pink flakes.	Approx. 1 (100°C)	98% or higher	<0.006 w.; >127 acet.; >110 ac. a.; 975 me. alc.; 257 pine oil.	Oral LD ₅₀ 2.4-3.1 g/kg	None.	Low.
13 Dowicide 6	Tetrachlorophenol (2, 3, 4, 6)	231.9	56.0	Light brown flakes to a sublimed mass.	Approx. 1 (100°C)	92%	<0.1 w.; 570 acet.; 189 bz.; 392 al.; 412 eth.; 319 me. alc.	Moderately toxic orally.	Absorbed.	Slight.
14 Dowicide 7; Santophen	Pentachlorophenol	266.3	190.2 (pure); 167-176 (technical)	White, needle-like crys. (pure); dark flakes and sublimed crys. (technical.)	1.1x10 ⁻⁴ (20°C); 0.12 (100°C)	Usually 83%	14 ppm w. (20°C); 21.5% acet. (20°C); 11.0 bz. (20°C); 57.0 me. alc. (20°C).	Oral LD ₅₀ 80mg/kg.	Absorbed.	Low; irritant, dust & vapor. ^{2, 5}
15 Glyodin	2-Heptadecylglyoxalidine acetate	368.6	62-68	Light orange crystalline solid.		(?)	i. w.; acet., toluene; s. (39%) isopropyl alc.	Oral LD ₅₀ 1.34g/kg.	Slight.	Irritant. ⁵
16 Milmer I; Bioquin; Copper-8	Copper-8-quinolinolate	351.8	Does not melt	Yellowish-green powder.	Practically nil	85% or higher	<0.002 w.; 0.98 ac. a.; <0.009 bz.; <0.01 al.; s. chl.	Large.	None.	Slight.
17 p-Nitrophenol	p-Nitrophenol	139.1	111.4-114	Colorless or yellow prisms.	0.083 (100°C)	(?)	1.6 w.; 21.2 h. w.; 54.4h. tol.; 189.5 al.	s.c. MLD 0.6 g/kg (rabbit).		Slight. ⁶
18 Phenylmercuric acetate	Phenylmercuric acetate	336.7	149-153	Small white lustrous prisms.	Very low	(?)	0.5 w.; 2.9 h. w.; 5 al.; 1.8 bz.; sl. s. pet. solvents.	S.c. LD ₅₀ 27mg/kg.	None. 1g/L causes blistering.	
19 Phenylmercuric oleate	Phenylmercuric oleate	558.9	212 d.	Amorphous solid.	Non-volatile	10%	i. w.; s. most hydrocarbon solvents.	MLD about 133mg/kg.	Absorbed.	Irritant. ⁵
20 Pyridylmercuric stearate	Pyridylmercuric stearate	562.2	120-130 d. at 200°C	White powder.			0.01 w.; 0.3 acet.; 0.8 bz.; 1.5% gly.			
21 Semesan; Uspulun	2-Chloro-4-(hydroxy-mercuri)phenol	345.2		Pink-white powder.	Low volatility.		i. w.; most org. solvents; s. a., alk.	Highly toxic.	Absorbed.	Irritant. ⁷
22 Shirlan	Salicylanilide	213	134-140; d. at 142°C	White crys. (pure), cream powder (technical).	Volatile with steam.	High	0.005 w.; 47 acet.; 11.6 al.; 8.0 eth.; 49 ac. a.	MLD about 1g/kg.	Poor.	None(?).
23 Sorbic acid	2, 4-Hexadienoic acid	112.1	134.5	Colorless solid. Colorless needles from water.	0.01 (20°C)	Close to 100%	0.6 gly.; 5.8 propylene glycol; 9.2 acet. (20°C).	Oral LD ₅₀ 10.5g/kg.	Poor.	Irritant. ⁸
24 Sulphur, lime	Calcium polysulfides			Orange-red liquid.	Non-volatile		i. w.	Oral LD ₅₀ 0.25-0.5g/kg.	Absorbed.	Slight; irritant, eye.
25 Thiram; Thirurad; Tuads	Tetramethylthiuram disulfide	240.4	155-156	White powder or grains.			<0.005 w.; 3.1 acet.; 5.0 bz.; 15 chl.; 1.6 toluene.	Oral LD ₅₀ 860mg/kg.	Absorbed.	Irritant. ⁵
26 Zineb	Zinc ethylenebisdithiocarbamate	275		White solid.	Negligible at 25°C		i. w.; s. pyr.	Oral LD ₅₀ 5.2g/kg.	Poor.	Slight.
27 Ziram; Milban; Zimate	Zinc dimethyldithiocarbamate	305.8	246 (pure) ⁹	White solid.	Negligible at 25°C		<0.008 w.; 0.33 acet.; 0.74 chl.; s. CS ₂ .	Oral LD ₅₀ 1.4± 0.1g/kg.	Poor.	Irritant. ⁵

1/ Abbreviations: a. = acid; ac. a. = acetic acid; acet. = acetone; al. = ethyl alcohol (95%); alc. = alcohol; alk. = alkali; bz. = benzene; c. = cold; chl. = chloroform; crys. = crystals; d. = decomposes; dil. = dilute; eth. = ether; gly. = glycerol; h. = hot; i. = insoluble; me. = methyl; MLD = minimum lethal dose; org. = organic; pet. = petroleum; ppm = parts per million; ppt. = precipitate; pyr. = pyridine; s. = soluble; s. c. = subcutaneous; sl. = slight; tol. = toluene; w. = water. 2/ To nose and throat. 3/ 158-171 (technical). 4/ To skin and respiratory tract. 5/ To skin. 6/ May cause dermatitis. 7/ Strongly irritant and sensitizing. 8/ Eye injury in rabbits. 9/ 240-244 (technical).

354. "ESSENTIAL" DRUGS

The question "If you were limited to the use of only 25 drugs in your practice, which would you choose?" was presented to several hundred clinicians, dentists, and veterinarians throughout the United States. The total response, entailing some 600 compounds, was statistically analyzed and the results are tabulated below -- 30 drugs in each professional category listed in order of preference. Biologicals were not included.

Drug ¹		Use	Drug ¹		Use
CLINICIANS					
1	Atropine	Anti-parasympatholytic, antispasmodic, mydriatic.	16	Iron	In nutritional iron deficiencies.
2	Morphine	Analgesic, narcotic.	17	Ether, diethyl	Inhalation anesthetic.
3	Penicillin	Antibiotic.	18	Sulfadiazine	Bacteriostat and bactericide.
4	Adrenal cortical hormones (ACH)	In adrenal insufficiency, rheumatoid arthritis, rheumatic fever, allergies, hay fever, bronchial asthma.	19	Adrenocorticotrophic hormone (ACTH)	In adrenal cortical insufficiency; see Item 4.
5	Acetylsalicylic acid (Aspirin)	Analgesic, antipyretic.	20	Meperidine hydrochloride (Demerol HCl)	Analgesic, antispasmodic; similar to morphine.
6	Digitalis	Myocardial stimulant in congestive heart failure.	21	Gantrisin (a sulfisoxazole)	Wide-spectrum antibacterial.
7	Tetracycline	Antibiotic.	22	Pentobarbital (Nembutal)	Hypnotic, sedative, antispasmodic.
8	Epinephrine (Adrenalin)	Sympathomimetic, antispasmodic, vasoconstrictor.	23	Alcohol, ethyl	CNS depressant, sedative, nutrient, antiseptic, solvent.
9	Vitamin B complex	In Vitamin B deficiencies.	24	Aminophylline	Diuretic, antispasmodic, cardiac and respiratory stimulant.
10	Streptomycin	Antibiotic.	25	Diphenylhydantoin sodium (Dilantin Na)	Anticonvulsant in epilepsy, chorea, and similar conditions.
11	Codeine	Analgesic, sedative, narcotic, antitussive.	26	Ephedrine	Sympathomimetic, vasoconstrictor, nasal decongestant.
12	Phenobarbital (Luminal)	Long-acting sedative, hypnotic, antispasmodic.	27	Ergot	Oxytocics.
13	Procaine (Novocaine)	Local anesthetic.	28	Chloramphenicol (Chloromycetin)	Wide-spectrum antibiotic.
14	Thyroid	In replacement therapy, obesity, myxedema, low BMR.	29	Oxygen	With inhalation anesthesia; treatment or prevention of hypoxia.
15	Insulin	In diabetes mellitus, hypoglycemic shock therapy.	30	Quinidine	In auricular fibrillation and tachycardia.
DENTISTS					
31	Procaine (Novocaine)	See Item 13.	46	Ammonia, aromatic spirit	Analeptic in syncope; antacid.
32	Eugenol (eugenic acid, allyl guaiaccol)	Local anesthetic and antiseptic.	47	Pentobarbital (Nembutal)	See Item 22.
33	Codeine	See Item 11.	48	Sodium fluoride	Inhibition of tooth decay.
34	Epinephrine (Adrenalin)	See Item 8.	49	Calcium hydroxide	Neutral base for temporary fillings and pulp capping.
35	Acetylsalicylic acid (Aspirin)	See Item 5.	50	Benzalkonium chloride (Roccal)	Surface antiseptic.
36	Alcohol, ethyl	Aid in drying cavities; see also Item 23.	51	Silver nitrate	Antiseptic, astringent, caustic.
37	Iodine (tincture)	Local antiseptic.	52	Zinc chloride	Antiseptic, astringent, caustic.
38	Nitrous oxide (N ₂ O)	Inhalation anesthetic and analgesic.	53	Glycerol	Solvent, emollient, plasticizer.
39	Penicillin	See Item 3.	54	Ethylaminobenzoate (Benzocaine)	Local anesthetic.
40	Zinc oxide	In dental cements.	55	Sodium bicarbonate	In mouth wash.
41	Lidocaine (Xylocaine)	Infiltration anesthesia; nerve block.	56	Gentian violet	Local antiseptic.
42	Oxygen	See Item 29.	57	Phenobarbital (Luminal)	See Item 12.
43	Phenol	Local antiseptic and anesthetic.	58	Tetracycline	See Item 7.
44	Hydrogen peroxide (H ₂ O ₂)	Bleaching and disinfecting agent; used in dentifrices, mouthwashes.	59	Nitromersol (Metaphen)	Local antiseptic.
45	Creosote, beechwood	Local antiseptic and anesthetic; in sterilization of root canals.	60	Petrolatum, liquid	Lubricant, solvent, vehicle.
VETERINARIANS					
61	Tetracycline	See Item 7.	77	Iron	See Item 16.
62	Penicillin	See Item 3.	78	Streptomycin	See Item 10.
63	Phenothiazine	Anthelmintic for pinworms, roundworms.	79	Petrolatum, liquid	See Item 60.
64	Procaine (Novocaine)	See Item 13.	80	Arecoline hydrobromide	Teniacle for dogs, cats; cathartic for horses.
65	Dextrose (glucose)	Parenteral nutrient solution.	81	Sodium fluoride	Insecticide, anthelmintic for roundworms of swine.
66	Iodine (tincture)	See Item 37.	82	Benzalkonium chloride (Roccal)	See Item 50.
67	Pentobarbital (Nembutal)	See Item 22.	83	Sulfamerazine	Bacteriostat.
68	Calcium gluconate	In milk fever (cattle), preg. disease (sheep); in convulsions, eclampsia, paraplegia (cats, dogs); in Mg, Hg, Pb, CCl ₄ poisonings.	84	Sulfamethazine	Bacteriostat.
69	Chloral hydrate	Narcotic, anesthetic; in tetanus, colic (horses), convulsions, strychnine poisoning.	85	Sulfaquinoxaline	Prevention and control of cecal and intestinal coccidiosis of fowl.
70	Ether, diethyl	See Item 17.	86	Tetrachloroethylene	Anthelmintic for hookworms.
71	Nemural (a diocarbyl)	Teniacle.	87	Adrenal cortical hormones (ACH)	See Item 4.
72	Alcohol, ethyl	See Item 23.	88	N-Butylchloride (Chlorobutane)	Anthelmintic.
73	Magnesium sulfate	Cathartic.	89	Epinephrine (Adrenalin)	See Item 8.
74	Hexachlorocyclohexane (Lindane)	Insecticide.	90	Acetylsalicylic acid (Aspirin)	See Item 5.
75	Morphine (salts)	See Item 2.			
76	Posterior pituitary	Oxytocic, pressor, antidiuretic.			

¹/ Drugs listed may include, or be interpreted in terms of, salts, closely related derivatives, or preparations. The eight drugs or drug types unanimously selected in all categories are: codeine (or morphine), acetylsalicylic acid, procaine, alcohol, epinephrine, a barbiturate (either phenobarbital), penicillin, and tetracycline.

355. COMMON POISONS: SYMPTOMS, PROCEDURES, AND ANTIDOTES

The symptoms indicated below may result from numerous pathological conditions or from exposure to many factors other than those given in the table. They may also vary in severity and order of appearance, according to the nature and amount of the toxic agent. This table lists examples of some common household poisons and therapeutic drugs which exert a toxic effect.

Part I: CHARACTERISTIC SYMPTOMS

Symptom	Poison
Circulatory	
1 Blood cell changes	Anemia: alcohol(chronic), arsenic, barbiturates(chronic), benzene(chronic), lead, morphine(addiction), naphthalene, sulfonamides; brown blood(Meth Hb): acetanilid, antipyrine, nitrites, nitrobenzene, nitroglycerin, phenacetin, potassium chlorate, sulfanilamide, sulfites; leucocytosis: chloral hydrate, pilocarpine, atropine; leucopenia: aminopyrine, aniline derivatives, arsenicals, benzene, sulfonamides; polycythemia: aniline derivatives(chronic), arsenic(dysentery); stippling: lead.
2 Bradycardia	Barium, digitalis, muscarine, physostigmine, pilocarpine, quinine, strophanthin, tetraethyl lead, veratrum.
3 Collapse(circulatory)	May be produced by practically any poison.
4 Hemorrhage, petechiae, purpura	Arsenic, benzene, corrosives, dicumarol, heparin, sedormid, warfarin.
5 Hypertension	Amphetamine, barium, ephedrine, epinephrine.
6 Hypotension	Apresoline, barbiturates(acute), chloroform, hexa- and pentamethonium compounds, histamine, muscarine, nitrites and nitroglycerin, tribromethanol, veratrum.
7 Tachycardia	Amphetamine, atropine, cocaine, ephedrine, epinephrine.
8 Vasoconstriction, gangrene	Amphetamine, ephedrine, epinephrine, ergot, lead, nicotine.
9 Coma or drowsiness	Alcohol, aniline, anesthetics, arsenic, antihistaminics, atropine, barbiturates, bromides, carbon disulfide, carbon monoxide, carbon tetrachloride, chloral hydrate, cyanides, gasoline, kerosene, methyl bromide, methylchloride, organic phosphate insecticides ¹ , opiates, synthetic morphine-like analgesics ² , phenol, sulfanilamide, sulfides.
10 Constipation	Calcium salts, dihydromorphinone, lead, opiates, synthetic morphine-like analgesics. ²
Convulsive	
11 Clonic	Abrin and castor beans, atropine, caffeine, camphor, carbon disulfide, ergot, insulin(inj.), phenol, picrotoxin, strychnine(early), theophylline.
12 Tonic or tetanic	Camphor, carbon monoxide, cocaine, cyanides, insulin(inj.), metrazol, nicotine, organic chloride insecticides ³ , organic phosphate insecticides ¹ , procaine, strychnine.
13 Tremor	Alcohol, amphetamine, arsenic, barium, ergot, ephedrine, insulin(inj.), lead, manganese(chronic), mercury(chronic), nicotine, physostigmine.
14 Diarrhea	Abrin and castor beans, antimony, arsenic, barium, corrosives, croton oil, digitalin group, emetine, ergot, mercury, muscarine, nicotine, organic phosphate insecticides ¹ , physostigmine, pilocarpine.
15 Hyperthermia(fever)	Arsenicals, atropine, barbiturates(early), camphor, cocaine, dinitrophenols, phosphorus, sulfonamides, salicylates.
16 Hypothermia	Alcohol, anesthetics, aniline derivatives, chloral hydrate, coal tar analgesics and antipyretics, opiates and synthetic morphine-like analgesics(except demerol) ² , nitrites, phenol.
17 Mania or delirium	Alcohol(chronic), amphetamine, atropine, barbiturates(chronic), bromides, camphor, cannabis, cocaine, ephedrine, insulin(inj.), lead, mercury, phenol, physostigmine, scopolamine.
18 Odor of breath	Acetone(diabetes, ingestion, starvation), alcohol, ammonia, camphor, chloroform, cyanides, methylsalicylate, nitrobenzene, paraldehyde, phenols, phosphorus, sulfides, other odoriferous poisons.
19 Paralysis	Abrin and castor beans, alcohol, arsenic, barium, carbon disulfide, lead, nicotine, triorthocresyl phosphate.
Pupillary	
20 Dilation	Alcohol, amphetamine, atropine, barbiturates, cocaine(early), ephedrine, homatropine, scopolamine.
21 Constriction	Codeine, ergot, opiates and synthetic morphine-like analgesics ² , muscarine, neostigmine, nicotine, organic phosphate insecticides ¹ , physostigmine, pilocarpine.
22 Fixation	Acetanilid, alcohol, anesthetics, chloral hydrate, coal tar analgesics, paraldehyde, somnifacients.
23 Respiratory depression	Alcohol, ANTU, barbiturates, barium, carbon disulfide, carbon tetrachloride, cyanides, opiates and synthetic morphine-like analgesics ² , organic phosphate insecticides ¹ .
Sensory	
24 Abdominal pain and colic	Arsenic, barium, carbon disulfide, cathartics(drastic), corrosives, fluorides, lead, mercury, methyl alcohol, muscarine, nicotine, organic phosphate insecticides ¹ , oxalates, physostigmine, pilocarpine.
25 Blindness and deafness	Atropine, barium, cocaine, digitalis, ergot, methyl alcohol, nicotine, quinine, salicylates.
26 Color vision	Digitalis, santonin.
27 Paresthesia	Alcohol, arsenic, carbon disulfide, ergot, lead, mercury.
28 Vertigo	Alcohols, anesthetics, antihistaminics, barbiturates, carbon monoxide, cyanides, ergot, fluorides, gasoline, histamine, kerosene, methadone, nicotine, nitrites, opiates and synthetic morphine-like analgesics ² , quinine, salicylates.
Dermal	
29 Corrosion(incl. mucosa)	Acids, alkalis, cresol, phenol.
30 Cyanosis	Acetanilid, alcohol, anesthetics, aniline, barbiturates, cyanides, gasoline, kerosene, nitrates, nitrobenzene, phenacetin, sulfanilamide, sulfides.
31 Discoloration (incl. tongue, oral mucosa)	Black: sulfuric acid; brown: bromine, iodine; greenish-blue: Paris green, other copper salts; white: alkalis, corrosive acids, metallic salts, phenol; yellow: nitric and picric acids; gingival line: bismuth, copper, lead, mercury, silver.
32 Dryness of mouth	Antihistaminics, atropine, ephedrine, scopolamine.
33 Edema	Arsenic, cortisone and derivatives, cresol, mercury, oxalates, phenol, turpentine.
34 Epilation	Alkali sulfides, radium, thallium.
35 Exfoliation	Arsenic, gold, sulfonamides.
36 Flush	Alcohol, anesthetics, arsenic, atropine, borates, carbon disulfide, carbon monoxide, cyanides, histamine, nicotinic acid, opium derivatives, pilocarpine.
37 Jaundice	Arsenic, bismuth, carbon tetrachloride, chloroform, cinchophen, gold, phosphorus, sulfonamides.
38 Pallor	Arsenic, barbiturates, cocaine and other local anesthetics, ephedrine, lead.
39 Rash	Can be caused by almost any drug, the more common being: antihistaminics, arsenicals, atropine, barbiturates, bromides, dyes, iodides, mercurials, procaine, quinine, radioactive substances, salicylates, sulfonamides.
40 Sweating	Acetanilid, antipyrine, emetics, opiates, phenacetin, physostigmine, pilocarpine, sulfonal.
41 Urticaria	Bromides, organic chloride insecticides ³ , histamine, phenobarbital, salicylates, sulfonamides.
Urinary	
42 Albuminuria	Arsenic, carbon tetrachloride, chlorates, chloroform, mercury, phenols, sulfonamides.
43 Color changes	Brown to black: naphthalene, phenol, pyrogallol, quinine, resorcinol; green: anthraquinone, methylene blue; orange: santonin; red: anthraquinone dyes, phenolphthalein(alkaline), santonin(alkaline).
44 Glycosuria	Ephedrine, morphine and opiates.
45 Hematuria	Arsenic, cantharides, mercury, naphthalene, oxalates, phenols, sulfonamides.
46 Oliguria	Arsenic, carbon tetrachloride, chromate, mercury(late stages), oxalates, phenols, sulfonamides.
47 Odor	Turpentine.
48 Polyuria(early); anuria(later)	Mercurials.
Vomiting	
49 Gastrointestinal irritation	Abrin and castor beans, alcohol, alkaline sulfides, antibiotics, antimony, arsenic, copper, cyanides, emetine and other ipecac alkaloids, gasoline, iodine, kerosene, mercury, naphthalene, phenol, strong acids and alkalis(also ammonia).
50 Systemic poisoning	Antihistaminics, apomorphine, atropine, camphor, carbon disulfide, cyanides, DDT(?), digitalis and other cardiotonic glycosides, emetine and other ipecac alkaloids, nicotine, organic chloride insecticides ³ , organic phosphate insecticides, phenol, picrotoxin, quinine, salicylates, strychnine, sulfonamides.

/1/ DFP, HETP, malathion, parathion, TEPP, etc. /2/ Levorphan(dromoran), meperidine(demerol), methadone, etc. /3/ Chlordane, lindane, etc.

355. COMMON POISONS: SYMPTOMS, PROCEDURES, AND ANTIDOTES (Concluded)

The symptoms indicated below may result from numerous pathological conditions or from exposure to many factors other than those given in the table. They may also vary in severity and order of appearance, according to the nature and amount of the toxic agent. This table lists examples of some common household poisons and therapeutic drugs which exert a toxic effect.

Part I: CHARACTERISTIC SYMPTOMS (concluded)

Symptom	Poison
51 Vomiting (concluded) Vomitus, colored	Blue: with iodine if starch is present; brown or "coffee grounds": alkaline or acid corrosives; green: copper sulfate, Paris green, Scheele's green.

Part II: GENERAL PROCEDURES

Poisons Taken Orally	
1	If nature of poison is unknown, give 15g of "universal antidote" (finely divided activated charcoal, 2 parts; tannic acid, 1 part; magnesium oxide, 1 part) in half a glass of warm water; if this preparation is not available, give large amounts of water, tea, milk or eggs. If poison is known, give specific antidote. Caution: Never give anything by mouth to an unconscious person.
2	Induce vomiting by stroking back of tongue from side to side, or by giving plenty of warm salt water or soapy water; or wash stomach promptly by means of tube. Caution: Do not use these procedures (a) where corrosive poisons have been ingested >30 minutes (danger of perforation of stomach or esophagus), or (b) in strychnine poisoning (danger of convulsions). With infants, avoid aspiration of vomitus into trachea or lungs by placing child face down when first retching appears, with head at least 8-10 inches lower than hips. Apomorphine injected subcutaneously is very effective emetic, but should be avoided in coma or respiratory depression.
3	Give cathartic, 15g of sodium sulfate or 30g of magnesium sulfate in half a glass of water; flush bowel by high colonic irrigation with warm water.
Poisons Inhaled	
4	Try to identify toxic vapor. In areas contaminated with ammonia, arsine, carbon monoxide, chlorine, bromine, fluorine, hydrogen cyanide, hydrogen sulfide, nitric vapors, or other highly toxic gases (i.e., CW agents), proper masks should be worn or the breath held.
5	Remove the victim promptly from exposure.
6	At first sign of difficult breathing begin artificial respiration, using approved method; oxygen should be administered only by trained personnel; continue artificial respiration until professional medical personnel arrive.
Poisons in Contact with the Skin	
7	Try to identify the poison, avoiding personal contact with it.
8	Flood the contaminated area with successive increments of water for at least 15 minutes.
9	Remove all contaminated clothing, including gloves, headgear, shoes, watches, rings, jewelry.
10	Do not use oils, fats or pastes (sodium bicarbonate, etc.), or bandages, unless specifically indicated.
Poisons in Contact with the Eyes	
11	Promptly flood both eyes with copious amount of water, with the eyelids open (eyelids can be opened and held apart by grasping the eyelashes and pulling the eyelids away from the eyeball). Using this method, continue washing for at least 15 minutes.
Other Precautions	
12	Keep the patient warm and in a recumbent position; never leave him unattended.
13	If breathing is difficult or has stopped, give artificial respiration, and continue until voluntary respiration reappears or medical aid arrives.
14	Do not give alcoholic beverages except on proper medical advice; alcohol increases the absorption of some poisons.
15	Send for medical assistance as soon as possible, but do not interrupt the procedures outlined above.

Part III: SPECIFIC ANTIDOTES

The "General Procedures" (G. P.) referred to below are found in Part II above.

i. m. = intramuscular injection; i. v. = intravenous injection; s. c. = subcutaneous injection.

Poison	Antidote
1 Acids, strong (CH_3COOH , HCl , HNO_3 , H_2SO_4 , H_3PO_4)	Use G. P. 1, or milk of magnesia; do not give carbonates or emetics.
2 Alcohol, methyl (wood alcohol)	Use G. P. 2, 3; 3-5% sodium bicarb. and 5% glucose, i. v., or orally if patient is conscious.
3 Alkalies, strong (NaOH , KOH , NH_4OH , K_2CO_3 , Na_2CO_3)	Large amounts 1% acetic acid or vinegar (4 x dil.) orally, then milk, white of eggs; do not use stomach tube or induce vomiting.
4 Alkaloids	Use G. P. 1, 2, 3, or gastric lavage with 0.01% potassium permanganate.
5 Belladonna (atropine, hyoscyamine, solanine, stramonium)	Same as above, then pilocarpine i. v., and pentobarbital i. m. or i. v.
6 Cocaine	Use G. P. 1, 2, 3; pentobarbital i. m. or i. v., to control convulsions.
7 Ergot (ergotamine, etc.)	Use G. P. 1, 2, 3; amyl nitrite inhalation, nitroglycerin s. c., papaverin i. v.
8 Muscarine, physostigmine, pilocarpine	Atropine i. v. or s. c. immediately and until symptoms are controlled, then G. P. 1, 2.
9 Nicotine (tobacco, "Black Leaf 40")	Ephedrine i. m., or amphetamine i. v. Do not give strychnine. G. P. 1, 2.
10 Opium (codeine, heroin, laudanum, morphine), synthetic morphine-like analgesics.	Gastric lavage with 0.1% potassium permanganate; N-allyl morphine i. v.; caffeine, sodium benzoate s. c., to stimulate respiration.
11 Strychnine	Pentobarbital i. v. immediately, or inhalation anesthesia to control convulsions; gastric lavage with 0.1% potassium permanganate only after convulsions have ceased; keep quiet, in absolute darkness; no morphine.
12 Arsenicals (As_2O_3 , Fowler's sol., Paris green, insecticides, rodenticides, Scheele's green)	G. P. 1, 2, 3; then BAL ¹ i. m., repeated doses; 30-60g Na or Mg sulfate in warm water, orally.
13 Barbiturates (barbital, luminal, nembutal, pentobarbital, phenobarbital, veronal)	G. P. 1, 2; amphetamine, metrazol or picrotoxin i. v., repeated until muscle excitation or recovery.
14 Barium salts (acetate, chloride, carbonate, sulfide)	Sodium or magnesium sulfate in warm water, orally; G. P. 2, 3.
15 Chloral hydrate	Gastric lavage with tea or coffee; picrotoxin, amphetamine or ephedrine i. v. until conscious.
16 Cyanides (HCN , KCN , NaCN)	Amyl nitrite inhalation immediately, then 3% sodium nitrite i. v. and 25% sodium thiosulfate i. v.
17 Formaldehyde (ingested)	Milk, eggs, ammon. acetate (15g in glass of water), or 0.2% ammonia water freely by mouth; G. P. 2.
18 Fluorides [HF , NaF , NH_4F , Na fluoroacetate (1040)]	Ca gluconate i. v. immed.; glass of lime water or 1% of CaCl_2 orally, or as gastric lavage.
19 Halogens (bromate, bromine, chlorate, iodine)	Sodium thiosulfate 15g in glass of water or starch solution; G. P. 2 and 3.
20 Lead compounds	Acute: gastric lavage with magnesium, sodium or aluminum sulfate solution, followed with plain water to remove lead sulfate thus formed; milk, eggs. Chronic: sodium calcium versenate 3% in glucose solution, by slow intravenous drip.
21 Mercury compounds	Orally, glass of 5-10% sodium phosphite or sodium formaldehyde sulfoxalate solution; G. P. 2, 3; BAL ¹ i. m.
22 Organic and fluorophosphates [diisopropyl fluoro-phosphate (DFP), hexaethyltetraphosphate (HETP), "nerve gas," parathion, tetraethylpyrophosphate, etc.]	Atropine sulfate i. m. or i. v. immediately, until symptoms subside; if poison swallowed, give milk, induce vomiting (G. P. 2); long-continued artificial respiration may be necessary.
23 Oxalic acid and oxalates	Orally or by stomach tube, lime water, magnesium oxide, chalk, or soluble calcium or magnesium salts; gastric lavage if mucosa not deeply corroded (burning pain, collapse); 10% calcium gluconate or 5% calcium chloride i. v. for tetany; later, magnesium sulfate purge.
24 Phenols (carbolic acid, creosote, cresol, etc.)	Give olive oil by mouth; carefully pass small, well-lubricated tube and wash out stomach with olive oil; if olive oil not available, give milk or egg white. Skin: wash with 50% alcohol, glycerine, vegetable oils, or soapy water.
25 Phosphorus, yellow (rat poisons)	Copious, repeated gastric lavage with 1-2% copper sulfate or 0.1-1% potassium permanganate solutions, or normal saline; G. P. 3; no oils, fats or milk in diet.
26 Salicylates [acetylsalicylic acid (aspirin), methyl salicylate (oil of wintergreen), phenyl salicylate (salol), salicylic acid, sodium salicylate]	Gastric lavage with sodium bicarbonate, saline catharsis, glucose i. v.; stimulants.
27 Silver salts (AgNO_3)	Sodium chloride or tannic acid in water; G. P. 2, followed with milk or other demulcents.
28 Thallium salts (insecticides, rodenticides)	Gastric lavage with 1% sodium or potassium iodide; G. P. 2; stimulants, demulcents; BAL ¹ i. m.

/1/ BAL (British anti-lewisite); 2, 3-dimercapto-1-propanol; used as a 10% solution in peanut oil with 20% benzyl benzoate.

356. REPTILE VENOMS AND POISONINGS:

A = Bradykininogen; B = Carboxypolypeptidase; C = Catalase; D = Cephalinase; E = Cholinesterase; F = Desoxyribonuclease; G = Diaminoxidase; H = Ithinoxase; P = Lipase; Q = 5-Nucleotidase; R = Ophio-ATP-ase; S = Phospholipase; T = Phosphodiesterase; U = Phosphomonesterase; V = Polypepti-

	Animal, Distribution	Adult Length ft	Fibrinogen		Prothrombin		Enzyme Activity ¹	Mouse Toxicity ² mg/kg
			Coagulate	Destroy	Activate	Destroy		
Helodermatidae								
1	Gila monster (<i>Heloderma suspectum</i>), S.W.U.S.A., N.W. Mexico (chiefly Arizona and Sonora)	1½-2						LD ₅₀ (rat) 20.18 lyophilized venom
Colubridae ⁷ (Snakes)								
2	Boomslang ⁸ (<i>Dispholidus typus</i>), forested portions of Africa south of Sahara	4½-5½			+(?)		W	MLD 10.0
Elapidae ⁹ (Snakes)								
3	Adder, death (<i>Acanthophis antarcticus</i>), most of Australia, parts of New Guinea, nearby islands	2-3	+(?)		+(?)		E, L, N, O, R	LD ₁₀₀ (0.5-0.7)
4	Black, red-bellied (<i>Pseudechis porphyriacus</i>), E. Australia	4½-5½	+(?)		+(?)		N, O	LD ₁₀₀ 3.5
5	Brown, Australian (<i>Demansia textilis</i>), most of Australia	4-5					E, N, R	LD ₁₀₀ 0.25
6	Brown, giant or Taipan ¹¹ (<i>Oxyuranus scutellatus</i>), N. Australia	8-11	+(?)		+(?)			LD ₁₀₀ 0.17
7	Cobra, Indian (<i>Naja naja</i>), S. Asia to Indonesia, Formosa, Philippines	4-6	-	-	-	+	B, E, H, I, J, L, M, N, O, P, R, T, U, V, W	MLD 0.75 LD ₅₀ 0.5
8	Cobra, king ¹³ (<i>Ophiophagus hannah</i>), W. India, Burma, Philippines, Indonesia, S. China, Thailand	12-16					E, N, R	
9	Cobra, spitting (<i>Naja nigricollis</i>), Africa south of Sahara in savannah areas	5-6				+	E, L, N, R, W	MLD 0.5
10	Copperhead, Australian ¹⁴ (<i>Denisonia superba</i>), E. Australia	4½-5½	+(?)		+(?)		E, L, N, O, R	LD ₁₀₀ 1.2
11	Coral, Central American (<i>Micrurus nigrocinctus</i>), tropical Mexico through Panama	2-3½						
12	Coral, North American (<i>M. fulvius</i>), southern U.S.A. to N.E. Mexico	2-3½						LD(MLD?) 1.0
13	Coral, South American (<i>M. frontalis</i>), southern Brazil to northern Argentina	2-5	-	-	+	-	L, W	LD ₁₀₀ 2.5
14	Coral, subtropical (<i>M. corallinus</i>), subtropical South America	2-4					E, L, N, R	
15	Krait, common (<i>Bungarus candidus coeruleus</i>), India, Burma, Malay Peninsula, Java, Sumatra, Celebes	3½-4½					E, K, L, N, W	LD ₁₀₀ 3.0 LD ₅₀ 1.0
16	Krait, Formosan (<i>B. multicinctus</i>), S.E. China, Formosa	3-4		-(?)		-(?)		LD 0.1
17	Long-glanded ¹⁷ (<i>Maticora intestinalis</i>), Burma, Malay Peninsula, Java, Sumatra	1½-2						
18	Mamba, eastern green (<i>Dendroaspis angusticeps</i>), E. Africa, Ethiopia to Natal	6-13						MLD 0.75
19	Mamba, western green ¹⁸ (<i>D. viridis</i>), W. Africa	6½-8					E, L	LD ₁₀₀ 3.0
20	Ringhals (<i>Hemachatus haemachates</i>), S. Africa	3-4	+	-	±	-	E, N, R, T, U, W	LD ₅₀ 3.0
21	Tiger ¹⁹ (<i>Notechis scutatus</i>), most of Australia including Tasmania	4-5½	-	-	+	-	E, L, N, R, T, U, W	LD ₁₀₀ >0.24 LD ₅₀ (g. pig) 6.5 µg/kg
Viperidae ²⁰ (Snakes)								
22	Adder, night (<i>Causus rhombeatus</i>), most of Africa	2-3					W	MLD 15.0
23	Adder, puff (<i>Bitis arietans</i>), Africa, S. Arabia	2½-5	-	+	-	-	A, E, N, R, T, U, W	MLD 7.5
24	Viper, European (<i>Vipera berus</i>), British Isles, across N. Europe and Asia to Japan	1½-2½					A, N	Mean LD 6.5
25	Viper, gaboon ²² (<i>V. gabonica</i>), tropical Africa	4-5½	+	+			E, L, N, Q, R, S, W	MLD 20.0
26	Viper, horned or Sahara sand (<i>Cerastes vipera</i>), N. Africa, Arabia, S. Iraq ²³	1½-2					N	MLD 15.0
27	Viper, Jura (<i>Vipera aspis</i>), Central and S. Europe	2-3		+		+(?)	E, G, L, N, O, R, W	MLD 0.75
28	Viper, mountain (<i>V. lebetina</i>), S.E. Europe to Pakistan ²⁴	3½-5					E, N	Mean LD 22.0
29	Viper, Palestine (<i>V. palestinae</i>), Israel and surrounding area							
30	Viper, Russell's, Daboia, or Tic polonga (<i>V. russellii</i>), India, Burma, S. China, Formosa, Java ²⁵	4-5½	+	-	-	+	B, E, H, I, J, K, L, M, N, O, P, Q, R, T, U, V, W	MLD 1.0 LD ₅₀ 20.0
31	Viper, saw-scaled ²⁶ (<i>Echis carinata</i>), India, Iraq, Arabia, Africa north of equator ²⁷	1½-2½	+				B, E, I, J, L, N, R, V, W	MLD 5.0 LD ₅₀ 7.5
32	Viper, Sudan mole ²⁸ (<i>Atractaspis microlepidota</i>), eastern central Africa	1½-2½						
Crotalidae ²⁹ (Snakes)								
33	Boicotiara (<i>Bothrops cotiara</i>), southern Brazil, northern Argentina	1½-3					E, L, N	LD ₁₀₀ 15.0
34	Bushmaster ³⁰ (<i>Lachesis muta</i>), Costa Rica to northern South America	8-11					L, W	LD ₁₀₀ 57.0

/1/ Implies characteristic activity for enzyme but not its specific isolation. /2/ Dry venom administered subcutaneously unless otherwise stated. /3/ GOOD implies a mortality of less than 1%; FAIR, 2-10% mortality; GUARDED, 11-40% mortality; POOR, more for crotalid envenomation believed effective. /7/ Fangs rear, immovable, grooved; over 1000 species (few poisonous, none dangerously). /8/ Ar- /11/ Large, aggressive; long fangs. /12/ Also Cape cobra (*N. nivea*), S.W. Africa and Cape Province; Egyptian cobra (*N. haje*), N.E. and S. Africa; /15/ Also banded krait (*B. fasciatus*). Slightly lower mortality. /16/ Mortality 77%. /17/ Venom glands extend through anterior third of body. /18/ Ar- ammodytes), S.E. Europe and Asia Minor; fair prognosis; symptoms somewhat more severe. /22/ Heavy snake, very long fangs. /23/ In arid gressive; chiefly arid habitat. /28/ Small, burrowing snake; large fangs. /29/ Fangs front, movable, hollow; pit between eye and nostril; more than

CHEMICAL AND BIOLOGICAL CHARACTERISTICS

Diastase; I = Dipeptidase; J = Endopeptidase; K = Flavin adenine dinucleotide; L = Hyaluronidase; M = Invertase; N = L-Amino-acid oxidase; O = Lec-dase; W = Protease. Slash mark (/) through letter indicates enzyme activity not known to be present.

Symptoms of Envenomation in Man	Prognosis ³	Available Anti-serum	
Helodermatidae			
Local pain, swelling, hyperemia, weakness, hyperpnea, tinnitus, nausea, vomiting. Death by respiratory paralysis and cardiac failure. ⁴	(?) ⁵	No ⁶	1
Colubridae⁷ (Snakes)			
Local pain, swelling and hemorrhage, ecchymoses, bleeding from nose and mouth, sometimes from all mucous mem-branes and skin, headache, vomiting, collapse; temperature normal or subnormal.	Good	No	2
Elapidae⁹ (Snakes)			
Similar to poisoning by tiger except that peripheral circulatory failure is more common and hemorrhagic phenomena occur.	Guarded	Yes	3
Local pain and swelling, vomiting, hemorrhages from nose and mouth, prostration, hematuria. ¹⁰	Good	Yes	4
Latent period to 12 hr followed by abdominal pain, vomiting, headache, dizziness, weakness, rapid pulse and subnormal temperature, respiratory and circulatory collapse, hemoglobinuria and peripheral thromboses.	Guarded	Yes	5
Similar to tiger. Flaccid paralysis of limbs, intercostal and bulbar paralysis, often rapidly fatal.	Poor	Yes	6
Pain radiating from bite, edema, numbness, tremors, ptosis, drooping of head, salivation, speech difficulty, giddiness, muscular incoordination and weakness, blindness, progressive depression of respiration, convulsions, incontinence of urine and feces. Pupils react to light and heart beats after respiration ceases. ¹²	Guarded	Yes	7
Similar to poisoning by Naja spp. Symptoms develop rapidly, often death in 30-60 min.	Poor	Yes	8
Similar to poisoning by Naja spp. Frequently sprays venom at eyes. Contact produces acute, intense ophthalmia. Sys-temic poisoning does not occur by this route, and permanent damage to vision is rare.	Guarded	Yes	9
Similar to tiger. Rapid loss of muscle tone and consciousness, peripheral circulatory failure.	Guarded	Yes	10
Local numbness; minimal systemic symptoms. Few cases reported.	Fair (?)	No	11
Cyclic pains radiating from bite; somnolence, dyspnea, dysphagia, sweating; soreness of face, throat and eyes.	Guarded	No	12
Neurologic symptoms at site of bite; involvement of 3rd, 4th and 6th cranial nerves producing ptosis and diplopia. Pro-longed coagulation time.	Guarded	Yes	13
Numbness without pain at bite. Early: headache, swelling of face and lips; hyperesthesia, sore throat, ptosis, photo-phobia, normal pupillary reflex, vomiting, cramps, dyspnea, loss of muscle tone, tachycardia. Later: backache, irritability, salivation, bradycardia, dysuria, albuminuria.	Guarded	Yes	14
Little immediate pain or local reaction. Latent period to 12 hr followed by abdominal pain, staggering gait, dysphagia, dyspnea, ptosis, stiffness of jaws, coma, respiratory paralysis, cardiac failure. ¹⁵	Poor ¹⁶	Yes	15
Poisoning similar to common krait.	Guarded	Yes	16
Minimal local pain and edema. Later: faintness, unsteady gait, periods of mental confusion, choking sensation with swelling and soreness of throat and mouth, salivation, vomiting, diarrhea, sweating, dyspnea.	Good (?)	No	17
Local pain and swelling, vomiting, restlessness, drowsiness or collapse followed by coma. Dyspnea and respiratory failure.	Poor	Yes	18
Poisoning similar to D. angusticeps.	Guarded	Yes	19
Pain; dyspnea; weak, thready pulse; cyanosis; collapse. Sprays venom at eyes. Effects resemble N. nigricollis.	Fair	Yes	20
Latent period 15-60 min followed by nausea, vomiting, faintness, drowsiness, sweating. Later: dullness of sensation, staggering, dysphagia, slurred speech, ptosis, pupils dilated and do not react to light; rapid, weak pulse and respiration, progressive dyspnea and death from respiratory failure.	Poor	Yes	21
Viperidae²⁰ (Snakes)			
Local hemorrhages, swelling.	Good	Yes	22
Severe local edema, necrosis and sloughing, restlessness, weak pulse, dyspnea, gastrointestinal hemorrhages.	Guarded	Yes	23
Local pain and edema of bitten extremity, sometimes extending into trunk; hemorrhages along lymphatics. Little systemic reaction, sometimes vomiting, sweating, abdominal pain, faintness, cyanosis, shock. ²¹	Good	Yes	24
Pain, hemorrhagic edema, necrosis, severe shock, respiratory depression, pain in loins with hematuria, pupils dilated and do not react to light.	Guarded	Yes	25
Local pain, edema, fever, thromboses and cardiac collapse in severe cases.	Fair	Yes	26
Similar to V. berus but systemic symptoms prominent. Vomiting, diarrhea, dysuria, weakness, depression.	Good	Yes	27
Rapidly spreading edema and necrosis, cold sweat, thirst, nausea, vomiting. Severe cases show epistaxis and hematuria.	Fair	Yes	28
Local pain, edema, ecchymoses, abdominal pain, vomiting, diarrhea with bloody stools in severe cases, fever, periph-eral vascular collapse and shock. Autopsy: serosanguineous transudate in subcutaneous tissue and muscles with degen-eration of arteriole and capillary walls. Visceral hemorrhages especially under endocardium and in gastrointestinal mucosa.	Fair	Yes	29
Rapidly spreading edema with extravasation of blood, epistaxis and petechiae, abdominal pain, vomiting, paralytic ileus, collapse, shock, albuminuria, prolonged clotting time. Terminally: loss of consciousness, pupils fail to react to light, circulatory failure. Autopsy: subcutaneous hemorrhages especially near bite, meningeal congestion, blood in lungs.	Guarded	Yes	30
Local pain and edema, low platelet count with ecchymoses and hemorrhages from mucous membranes, profound anemia, abdominal pain, impaired liver function.	Guarded	Yes	31
Local pain followed by numbness, adenitis, tachycardia, sweating, salivation, vomiting, dyspnea and pulmonary conges-tion, microscopic hematuria.	Fair	No	32
Crotalidae²⁹ (Snakes)			
Inadequate information. Presumably similar to fer-de-lance.	Fair	Yes	33
Inadequate information. Rapid death preceded by a severe shock-like state.	Poor ³¹	Yes	34

Considerable geographic and individual variation in toxicity exists, e.g., *Ancistrodon contortrix*, *Bothrops jararacussu*, *B. neuweidii*, *Crotalus ter-tality* in excess of 40%. /4/ Nonaggressive, bite sometimes ineffective. /5/ Prognosis from good to poor, literature conflicting. /6/ Antiserum boreal, timid. /9/ Fangs front, grooved though virtually fused for most of length; over 150 species. /10/ Also Mulga snake (*P. australis*). black cobra (*N. melanoleuca*), W., Central and E. Africa south of Zululand in forests. /13/ Highly aggressive. /14/ Sluggish, seldom bites. boreal, quick, aggressive. /19/ Active, aggressive; short fangs. /20/ Fangs front, movable, hollow; about 50 species. /21/ Also sand viper (*V. habitat*. /24/ Occurs in mountains to 8000 ft. /25/ Often common in thickly settled areas. /26/ Also called carpet viper or phoorsa. /27/ Ag-80 species. /30/ Very aggressive, jungle habitat. /31/ Mortality usually 100%.

356. REPTILE VENOMS AND POISONINGS:

A = Bradykininogen; B = Carboxypolypeptidase; C = Catalase; D = Cephalinase; E = Cholinesterase; F = Desoxyribonuclease; G = Diaminooxidase; H = Ithinoxase; P = Lipase; Q = 5-Nucleotidase; R = Ophio-ATP-ase; S = Phospholipase; T = Phosphodiesterase; U = Phosphomonoesterase; V = Polypeti-

Animal, Distribution		Adult Length ft	Fibrinogen		Prothrombin		Enzyme Activity ¹	Mouse Toxicity ² mg/kg
			Coagulate	Destroy	Activate	Destroy		
Crotalidae ²⁹ (concluded)								
35	Cascabel (<i>Crotalus terrificus</i>), southern Mexico to Uruguay and Argentina, mostly in highlands	4-5½	+	-	±	-	E, F, L, N, R, W	LD ₁₀₀ 1.1 LD ₅₀ 0.6
36	Copperhead, North American (<i>Ancistrodon contortrix</i>), eastern and southern U.S.A.	2-3½					E, N, T, V, W	LD ₁₀₀ 53.0 LD ₅₀ 25.6
37	Fer-de-lance ³² (<i>Bothrops atrox</i>), central Mexico to eastern Argentina, islands of Martinique, Tobago, Trinidad, and St. Lucia	4½-6½	+	-	-	+	E, F, L, N, R, W	LD ₁₀₀ 31.0 LD ₅₀ 22.0
38	Habu (<i>Trimeresurus flavoviridis</i>), Riu Kiu Islands	4-5					R, T, U, W	LD ₁₀₀ 16.0
39	Jararaca (<i>Bothrops jararaca</i>), Brazil to northern Argentina and Paraguay	3½-4½	+	-	+	-	A, E, J, L, N, R, W	LD ₁₀₀ 7.0
40	Jararaca, painted (<i>B. neuwiedii</i>), Brazil and Bolivia to Argentina	2-3					E, F, L, N, R, W	LD ₁₀₀ 14.0 ³⁴
41	Jararacussu (<i>B. jararacussu</i>), Bolivia, Brazil, Paraguay, Argentina	4-6					E, F, L, N, W	LD ₁₀₀ 9.0
42	Massasauga or marsh rattlesnake (<i>Sistrurus catenatus</i>), southern Ontario, central and S.W.U.S.A.	2-3					E, N, R	LD ₁₀₀ 9.0 LD ₅₀ 5.2
43	Moccasin, water (<i>Ancistrodon piscivorus</i>), southern U.S.A. to central Texas	3-5	-	+	-	+	D, E, K, L, N, O, Q, T, V, W	LD ₁₀₀ 45.0 LD ₅₀ 25.8
44	Rattlesnake, eastern diamondback (<i>Crotalus adamanteus</i>), S.E.U.S.A. in lowlands	4½-6½	+	+	-	-	D, E, L, N, Q, T, V, W	LD ₅₀ 14.5
45	Rattlesnake, Mexican diamondback (<i>C. basiliscus</i>), western Mexico	4½-6½	+	-	-	-	E, N, R, W	LD ₁₀₀ 4.0
46	Rattlesnake, prairie or Pacific (<i>C. viridis</i>), western U.S.A., S.W. Canada, N. Mexico	2½-5					E, N	LD ₅₀ 3.6
47	Rattlesnake, red ³⁵ (<i>C. ruber</i>), extreme S.W.U.S.A., parts of California (Baja)	3-5					E, N	LD ₅₀ 21.2
48	Rattlesnake, timber (<i>C. horridus</i>), eastern U.S.A.	3-5	+	-	-	+	E, N, R, W	LD ₁₀₀ 9.2 ³⁶
49	Rattlesnake, western diamondback ³² (<i>C. atrox</i>), S.W.U.S.A., northern Mexico	3½-5½	-	+	-	-	A, E, L, N, R, W	LD ₁₀₀ 19.0 LD ₅₀ 7.5 ³⁷
50	Sidewinder or horned rattlesnake (<i>C. cerastes</i>), S.W.U.S.A. in deserts	1½-2½						LD ₅₀ 4.2
51	Timbo or jumping viper (<i>Bothrops mexicana</i>), southern Mexico through Central America	2-3	+	-	-	-	E, N, W	
52	Urutu (<i>B. alternata</i>), southern Brazil to Argentina	3-5					E, F, L, N, O, W	LD ₁₀₀ 23.0 LD ₅₀ 13.0 MLD 7.6
53	Viper, Chinese pit (<i>Trimeresurus mucrosquamatus</i>), S. E. China, Formosa	3-4						
54	Viper, hognosed (<i>Bothrops lansbergii</i>), Central America, Panama to El Salvador	1-1½						
55	Viper, Malay pit (<i>Agkistrodon rhodostoma</i>), Thailand, Java, Malay Peninsula, Sumatra	2-3						
56	Viper, palm ³⁹ (<i>Bothrops schlegelii</i>), British Honduras to Ecuador and Columbia	1½-3	+				W	

/1/ Implies characteristic activity for enzyme but not its specific isolation. /2/ Dry venom administered subcutaneously unless otherwise stated. /3/ GOOD implies a mortality of less than 1%; FAIR, 2-10% mortality; GUARDED, 11-40% mortality; POOR, more than 40%. /34/ 26 mg/kg also reported. /35/ Nonaggressive. /36/ 36 mg/kg also reported. /37/ 16.8 mg/kg also reported. /38/ Also Mamushi or

357. TOAD VENOMS: CHEMICAL

Toad, Distribution	Bufagins ¹			Bufotoxins ²	
	Name (Proposed Formula)	Action or Effect ⁴	Toxicity ⁵ mg/kg	Name (Proposed Formula)	
1 Bufo alvarius, S.W. U.S.A.		Absent		Alvarobufotoxin	
2 Bufo arenarum, Argentina	Arenobufagin (C ₂₅ H ₃₄ O ₆)	Digitalis-like; emesis; systolic standstill of heart.	0.092 ±0.005	Arenobufotoxin (C ₃₉ H ₆₀ O ₁₁ N ₁₄)	
3 Bufo bufo bufo (<i>B. vulgaris</i>), Europe		Absent		Vulgarobufotoxin (C ₃₈ H ₆₀ O ₁₁ N ₁₄)	
4 Bufo bufo gargarizans, China	Cinobufagin (C ₂₅ H ₃₁ O ₅) ⁷	Digitalis-like action on vagus, vagus center, myocardium; emesis; clonic or tonic convulsions after paralysis.	0.219 ±0.011	Cinobufotoxin (C ₄₃ H ₆₄ O ₁₂ N ₁₄ , or C ₃₉ H ₅₈ O ₁₁ N ₁₄)	
	Telecinobufagin (C ₂₄ H ₃₄ O ₅)		0.102 ±0.007		
5 Bufo formosus (<i>Bufo bufo japonicus</i>), Japan	Gamabufagin (C ₂₇ H ₃₈ O ₆) ⁸	Digitalis-like action; emesis; ventricular fibrillation.	0.101 ±0.005	Gamabufotoxin (C ₄₁ H ₆₄ O ₁₁ N ₁₄)	
6 Bufo marinus (<i>B. aqua</i>), circumtropical	Marinobufagin (C ₂₄ H ₃₂ O ₅)		0.555 ±0.028	Marinobufotoxin (C ₃₈ H ₅₈ O ₁₀ N ₁₄ , or C ₄₂ H ₆₂ O ₁₁ N ₁₄) ⁹	
7 Bufo quercicus, S.E. U.S.A.	Quercicobufagin (C ₂₃ H ₃₄ O ₅)		0.097 ±0.004	Quercicobufotoxin	
8 Bufo regularis pardalis, South Africa	Regularobufagin (C ₂₃ H ₃₄ O ₅)		0.153 ±0.006	Regularobufotoxin (C ₃₇ H ₆₀ O ₁₀ N ₁₄)	
9 Bufo terrestris-americanus, E. U.S.A.	Americobufagin	Digitalis-like action.		Americobufotoxin	
10 Bufo valliceps, eastern Mexico, Texas and Louisiana	Vallicepobufagin (C ₂₃ H ₃₄ O ₅)	Nausea; emesis; A-V block and ventricular standstill.	0.201 ±0.017	Vallicepobufotoxin	
11 Bufo viridis viridis, Europe	Viridobufagin (C ₂₃ H ₃₄ O ₅)	Nausea, emesis, increased intestinal tone, ventricular fibrillation.	0.111 ±0.008	Viridobufotoxin (C ₃₇ H ₆₀ O ₁₀ N ₁₄)	
12 Bufo woodhousei, S.E. U.S.A.	Fowlerobufagin (C ₂₃ H ₃₃ O ₆)	Digitalis-like action; emesis; ventricular fibrillation.	0.218 ±0.012	Fowlerobufotoxin	

/1/ The bufagins are steroid-type compounds and possess a digitalis-like action. /2/ The bufotoxins are the conjugation product of the specific buf- lethal or average fatal dose for cat, intravenous. /6/ Frog heart; heart perfusion method. /7/ Also reported C₂₉H₃₈O₇. /8/ Also reported as oc-

CHEMICAL AND BIOLOGICAL CHARACTERISTICS (Concluded)

Diastase; I = Dipeptidase; J = Endopeptidase; K = Flavin adenine dinucleotide; L = Hyaluronidase; M = Invertase; N = L-Amino-acid oxidase; O = Lec-dase; W = Protease. Slash mark (/) through letter indicates enzyme activity not known to be present.

Symptoms of Envenomation in Man	Prognosis ³	Available Anti-serum	
Crotalidae ²⁹ (concluded)			
Little local reaction other than swelling, intense headache, nausea, dizziness, blindness, paralysis of neck and of eyelids (ptosis), collapse, albuminuria and hematuria followed by anuria. Death from respiratory paralysis or uremia. Autopsy: hyperemia of brain and meninges, sometimes with hemorrhages; intermediate nephron necrosis.	Poor	Yes	35
Local pain, swelling and necrosis, lymphangitis and lymphadenitis, sweating, nausea, vomiting. In severe cases: shock, petechiae, bloody stools.	Good	Yes	36
Local pain, edema and lymphadenopathy, bleeding from fang punctures, gums, nose and other body orifices, low pro-thrombin, prolonged clotting time, moderate to high leukocytosis, hematuria. In severe cases: shock, pupils do not react to light, respiration irregular. Autopsy: hemorrhagic necrosis at bite; hemorrhages into muscles, bowel, central nervous system; blood incoagulable.	Guarded ³³	Yes	37
Marked local and regional edema, ecchymoses, anesthesia at site of bite, nausea and vomiting.	Fair	Yes	38
Similar to fer-de-lance. Autopsy: generalized visceral hemorrhages, cerebral hemorrhage, hemoglobinuric nephrosis.	Guarded	Yes	39
Presumably similar to poisoning by fer-de-lance.	Fair	Yes	40
Clinical and autopsy findings similar to fer-de-lance.	Guarded	Yes	41
Pain, edema, ecchymoses, weakness, sweating, vomiting, hemolytic anemia in severe cases.	Good	Yes	42
Similar to poisoning by N.A. copperhead, but more severe. Local necrosis more marked.	Fair	Yes	43
Local pain, edema and ecchymoses, dryness of mouth, vomiting, shock, hemolytic anemia. In severe cases: muscular twitching, paresthesia, speech difficulty, sensation of yellow vision, unconsciousness.	Guarded	Yes	44
Similar to cascabel, but less severe. Inadequate information.	Guarded	Yes	45
Usual local symptoms of Crotalus. Also thirst, abdominal pain, vomiting, diarrhea, dyspnea. In severe cases: excite-ment, hypertonicity of muscles, paresthesia, convulsions, cyanosis, respiratory failure, clouding of consciousness.	Fair	Yes	46
Similar to western diamondback but less severe.	Fair	Yes	47
Local pain, edema, vesication, pallor, vomiting, fever, restlessness, shock, anemia.	Fair	Yes	48
Similar to eastern diamondback but neurotoxic symptoms less marked. Profound shock in severe cases.	Guarded	Yes	49
Inadequate information. Presumably similar to prairie rattlesnake but less severe.	Fair	Yes	50
Local pain, edema and necrosis, minimal systemic reaction. Information meager, possibly unreliable.	Good (?)	Yes	51
Similar to fer-de-lance. Late death from CNS hemorrhage. Autopsy: massive subdural hemorrhage, dilated left heart, renal hemorrhage, cerebral edema.	Guarded	Yes	52
Local pain, ecchymoses, blistering, little systemic reaction.	Fair	Yes	53
Local pain and edema, minimal systemic reaction.	Good	Yes	54
Local pain, swelling and necrosis, pallor, weakness, rapid pulse, prolonged clotting time. ³⁸	Good	Yes	55
Local symptoms as with other Bothrops spp. Also headache, faintness, bleeding from gums.	Good	Yes	56

Considerable geographic and individual variation in toxicity exists, e.g., *Ancistrodon contortrix*, *Bothrops jararacussu*, *B. neuweidii*, *Crotalus ter-tality* in excess of 40%. /29/ Fangs front, movable, hollow; pit between eye and nostril; more than 80 species. /32/ Aggressive. /33/ Mortality about Pallas' pit viper (*A. halys*), S.E. Europe, across Asia to Japan. /39/ Arboreal.

AND BIOLOGICAL CHARACTERISTICS

Bufotoxins ²		Bufotenines ³			
Action or Effect ⁴	Toxicity ⁵ mg/kg	Name (Proposed Formula)	Action or Effect	Cardiac Arrest ⁶	Remarks
Digitalis-like; emesis; systolic standstill of heart.	0.756 ±0.075	Alvarobufenine (C ₁₂ H ₁₈ O ₂ N ₂)	Oxytocic; slight pressor action; diastolic standstill of heart.	1:5000 dil.	Cholesterol and ergos-terol present.
Digitalis-like; emesis; ventricular fibrillation.	0.406 ±0.012	Arenobufenine A (C ₁₂ H ₂₀ O ₃ N ₂) Arenobufenine B (C ₁₄ H ₁₈ O ₂ N ₂)	Oxytocic; slight pressor action.	1:5000 dil. 1:5000 dil.	Cholesterol and epinephrine present.
Emesis; ventricular fibrillation.	0.292 ±0.017	Vulgarobufenine (C ₁₂ H ₁₈ O ₂ N ₂)	Oxytocic; marked pressor action.		Cholesterol and ergosterol present.
Emesis; vasopressor effect, followed by cardiac collapse, death in systole; prolongation of P-R interval.	0.359 ±0.024	Cinobufenine (C ₁₂ H ₁₆ ON ₂)	Oxytocic; miotic; intense, short vasopressor action; contrac-tion of smooth muscle not inhibited by atropine.	1:10,000 dil.	Cholesterol, epinephrine, norepinephrine and bufotenidine present.
Persistent action; slight pressor ac-tion; emesis; ventricular fibrillation.	0.374 ±0.027	Gamabufenine (C ₁₂ H ₁₈ O ₂ N ₂)	Oxytocic; marked pressor action.	1:5000 dil.	Cholesterol, epinephrine, and bufotenidine present.
More emetic than bufagin.	0.417 ¹⁰ ±0.022	Marinobufenine (C ₁₂ H ₁₄ O ₂ N ₂)	Oxytocic; little or no pressor action.	1:5000 dil.	Epinephrine, cholesterol, ergosterol, 5-hydroxy-tryptamine also present.
Ventricular systolic standstill.		Quercicobufenine (C ₁₂ H ₁₈ O ₂ N ₂)	Oxytocic; slight pressor action.		Cholesterol present (?).
Emesis; ventricular fibrillation.	0.477 ±0.026	Regularobufenine	Oxytocic; marked pressor action.		Epinephrine present (4.3-5% of whole venom, 10.7 mg per animal).
Digitalis-like action.		Americobufenine. (C ₁₂ H ₁₈ O ₂ N ₂)	Oxytocic; marked pressor action.		
		Vallicepobufenine (C ₁₁ H ₁₂ O ₂ N ₂)	Oxytocic; slight pressor action; decreased amplitude and arrest of heart contractions.	1:1000 dil.	
Action similar to, but weaker than, that of viridobufagin.	0.270 ±0.012	Viridobufenine A (C ₁₂ H ₁₈ O ₂ N ₂) Viridobufenine B (C ₁₂ H ₂₀ O ₃ N ₂)	Oxytocic; marked pressor action. Oxytocic; slight pressor action.	1:5000 dil. 1:5000 dil.	Cholesterol and ergosterol present.
Emesis.	0.792 ±0.054	Fowlerobufenine (C ₁₃ H ₂₀ O ₂ N ₂)	Oxytocic; marked pressor ac-tion; epinephrine-like action.	1:5000 dil.	Bufotenidine present.

ogin with one molecule of suberyl-arginine. /3/ The bufotenines are organic bases having an indole ring in the molecule. /4/ On cat. /5/ Mean curring in *Bufo paracnemis* (Argentina). /9/ Also reported as C₄₂H₆₄O₁₁N₄. /10/ Also reported as 0.43 and 0.49.

Protozoa	
1	<p>PARALYTIC SHELLFISH POISONING caused by ingestion of mollusks which have fed on toxic dinoflagellates.</p> <p><u>Animal, Distribution.</u> Dinoflagellates: (<i>Gymnodinium breve</i>), Florida coast; (<i>Gonyaulax catenella</i>), U.S. Pacific coast, Gulf of Mexico; (<i>G. tamarensis</i>), Nova Scotia, Canadian Atlantic coast; (<i>Pyrodinium phoneus</i>), Belgium.</p> <p><u>Symptoms, Findings.</u> Symptoms may appear within 10 min after ingestion. Gastrointestinal and mental symptoms variable. Paresthesia of lips, tongue and fingertips followed by ataxia and muscular incoordination. Ascending paralysis. Death may occur from cardiovascular collapse or respiratory failure in 2-12 hr. Aphasia also reported. (See also Mollusca.)</p> <p><u>Chemistry, Toxicology.</u> Toxin a potent alkaloid soluble in alcohol and water, insoluble in ether and chloroform. Loses stability but not necessarily toxicity in aqueous solution with pH and temperature increase. Poison not isolated; postulated empirical formula of hydrochloride: $C_9H_{17}N_6O_4(HCl)_2$. Purest preparation has toxicity of 4 mouse units per μg. MLD for man is probably 5-10 mg. Neurotoxin with both central and peripheral actions. Depresses cardio-inhibitory and vasomotor centers and conduction system of myocardium.</p>
Porifera	
2	<p>SPONGE STING caused by contact.</p> <p><u>Animal, Distribution.</u> Brown sponge (<i>Fibulia nolitangere</i>), W. Indies; fire sponge (<i>Tedania ignis</i>), W. Indies; fire sponge (<i>T. toxicalis</i>), California coast.</p> <p><u>Symptoms, Findings.</u> Urticaria and pruritis with occasional swelling of affected areas.</p> <p><u>Chemistry, Toxicology.</u> Intraperitoneal injections of crude extracts of the animal lethal to mice. Kills aquarium animals.</p>
Coelenterata	
3	<p>HYDROID STING caused by contact. Venom apparatus of cnidoblasts comprised of capsule, nematocyst and cnidocil. Toxin is introduced through the tubular filament of the nematocyst. Chemical and mechanical factors appear to be involved in the discharge of the nematocysts.</p> <p><u>Animal, Distribution.</u> False; or stinging; coral (<i>Millepora alcornis</i>), eastern Florida, Malaya, tropical seas.</p> <p><u>Symptoms, Findings.</u> Acute burning sensation on contact. Erythema, pustule formation and desquamation reported.</p> <p><u>Chemistry, Toxicology.</u> Not known.</p>
4	<p>PHYSALIA STING caused by contact with nematocyst-bearing tentacles.</p> <p><u>Animal, Distribution.</u> Portuguese-man-of-war (<i>Physalia physalis</i>), Florida, Hawaii, Australia, warm seas.</p> <p><u>Symptoms, Findings.</u> Intense burning pain following contact. Erythematous wheals with occasional numbness. Gastrointestinal and mental symptoms reported, also muscular weakness and pain sometimes followed by clonic contractions. Respiratory distress in severe cases; secondary shock may develop. Skin lesions persist for weeks. Fatal cases reported.</p> <p><u>Chemistry, Toxicology.</u> Tentacles yield hypnotoxin, an anesthetizing substance, precipitated by alcohol, non-dialyzable, and destroyed by temperature above 55°C.</p>
5	<p>JELLYFISH STING caused by contact.</p> <p><u>Animal, Distribution.</u> Sea wasp (<i>Chiropsalmus quadrigatus</i>), Indian Ocean, Netherlands Indies, Australia; giant jellyfish (<i>Cyanea capillata</i>), north temperate and arctic seas; pink-fringed jellyfish (<i>Dactylometra quinquecirrha</i>), Florida coast, Philippines.</p> <p><u>Symptoms, Findings.</u> Symptoms similar to those provoked by <i>Physalia</i>; fatal cases reported from <i>Chiropsalmus</i> sting.</p> <p><u>Chemistry, Toxicology.</u> Meduso-congestin, an alcohol-precipitated toxin, has been isolated from certain jellyfish. Toxin has local effect on pilomotor muscles; causes spastic contractions. Hypersensitizes temperature perception organ in skin.</p>
6	<p>SEA ANEMONE STING caused by contact.</p> <p><u>Animal, Distribution.</u> Sea anemones: (<i>Actinia equina</i>), Black Sea; (<i>Actinodendron alcyonoideum</i>), Pacific coral reefs, Australia; (<i>Sagartia elegans</i>), Mediterranean and African Seas.</p> <p><u>Symptoms, Findings.</u> Stinging sensation on contact; may be followed by pruritis and edema. Severe cases may develop papules which occasionally ulcerate. Systemic symptoms and deaths reported. "Sponge fisherman's disease" thought to be caused by <i>Sagartia</i>.</p> <p><u>Chemistry, Toxicology.</u> Actinia toxin separated into two fractions: congestin and thalassin. Congestin is a water soluble, heat resistant, white crystalline substance that produces vomiting, diarrhea and visceral congestion. One-tenth g/kg animal produces death from respiratory paralysis. Thalassin is a water soluble, alcohol-precipitated crystal antagonistic to congestin. One-hundredth mg/kg animal causes intense scratching and sneezing in dogs. A curare-like fraction, tetramine, has been isolated from <i>Actinia equina</i>.</p>
Mollusca	
7	<p>CONE SHELL STING caused by contact. Wounds inflicted by hollow teeth attached to long slender, tubular, fleshy proboscis connected to a venom gland.</p> <p><u>Animal, Distribution.</u> Cloth-of-gold shell (<i>Conus auricus</i>), S. Pacific; cone shell (<i>C. geographus</i>), S. Pacific, Japan, Australia; cone shell (<i>C. marmoreus</i>), S. Pacific; cone shell (<i>C. tulipa</i>), S. Pacific.</p> <p><u>Symptoms, Findings.</u> Sting results in intense burning pain often followed by numbness. Area about wound is cyanotic and swollen. Muscular incoordination, paresis or paralysis, mental confusion, visual disturbances and paresthesia reported. In severe cases, respiratory distress and cardiovascular collapse. Deaths reported in 3-5 hr.</p> <p><u>Chemistry, Toxicology.</u> Not known.</p>
8	<p>PARALYTIC SHELLFISH POISONING caused by ingestion of mollusks. (See Protozoa.)</p> <p><u>Animal, Distribution.</u> Razor clam (<i>Ensis directus</i>), New England coast; bar or surf clam (<i>Macra solidissima</i>), New England coast; horse or red mussel (<i>Modiolus modiolus</i>), both N. American coasts, Europe; ocean mussel (<i>Mytilus californianus</i>), Pacific coast N. America; common or blue mussel (<i>M. edulis</i>), Europe, N. American coasts, New Zealand, S. Africa; butter clam (<i>Saxidomus giganteus</i>), Pacific coast N. America, Canada; butter clam (<i>S. nuttalli</i>), California coast.</p> <p><u>Symptoms, Findings.</u> (See Protozoa.)</p> <p><u>Chemistry, Toxicology.</u> (See Protozoa.)</p>
9	<p>VENERUPIN POISONING caused by ingestion.</p> <p><u>Animal, Distribution.</u> Venus shell (<i>Tapes semidecussata</i>), Japan.</p> <p><u>Symptoms, Findings.</u> Gastrointestinal upset.</p> <p><u>Chemistry, Toxicology.</u> Toxic principle, called venerupin, thought to be an amine. LD of purified poison is 0.25 mg for a 15 g mouse. Venerupin treated with acidulated ethanol becomes violently toxic to mice, resembling paralytic shellfish poisoning. Causes acute yellow or red atrophy of liver and hemorrhagic symptoms.</p>
10	<p>OCTOPUS BITE. Venom apparatus of anterior and posterior salivary glands, salivary ducts, buccal mass and beak. Bite is puncture-wound variety. Venom is secreted by posterior salivary gland.</p> <p><u>Animal, Distribution.</u> Octopuses: (<i>Eledone moschata</i>), Mediterranean Sea; (<i>Octopus apollyon</i>), Pacific coast N. America; (<i>O. macropus</i>), Europe, Mediterranean and Red Seas, Indian Ocean, Malaysia, China, Japan and Australia; (<i>O. vulgaris</i>), warm seas.</p> <p><u>Symptoms, Findings.</u> Symptoms variable. Bite usually produces sharp throbbing pain, tingling and edema lasting few hours to several days.</p> <p><u>Chemistry, Toxicology.</u> Not known.</p>
Annelida	
11	<p>WORM BITE.</p> <p><u>Animal, Distribution.</u> Bloodworm (<i>Glycera dibranchiata</i>), Caribbean Sea, N. Carolina to Massachusetts, Pacific coasts of Mexico and S. California.</p> <p><u>Symptoms, Findings.</u> Stinging pain, edema, increase localized skin temperature, pruritis for several hours.</p> <p><u>Chemistry, Toxicology.</u> Not known.</p>

- | Arthropoda | |
|---------------|--|
| 12 | <p>KING CRAB POISONING caused by ingestion.</p> <p><u>Animal, Distribution.</u> King or horseshoe crabs: (<i>Carcinoscorpius rotundicauda</i>), estuaries of Malaya and Siam; (<i>Tachyplesus gigas</i>), Japan, Malaya, India.¹</p> <p><u>Symptoms, Findings.</u> Onset of symptoms in 10 min to $\frac{1}{2}$ hour. Dizziness, nausea, vomiting, weakness, headache, paresthesia of lips and mouth, cardiac arrhythmia, drowsiness, possible paralysis of muscles of mastication and limbs. Death may occur in 1-6 hr. In non-fatal cases, recovery is prolonged.</p> <p><u>Chemistry, Toxicology.</u> Tissues contain powerful toxic alkaloid. Flesh and eggs of <i>Carcinoscorpius</i> can be fatal.</p> |
| Echinodermata | |
| 13 | <p>STARFISH POISONING caused by contact.</p> <p><u>Animal, Distribution.</u> Common starfish (<i>Crossaster papposus</i>), N. Atlantic coasts of Europe and America.</p> <p><u>Symptoms, Findings.</u> All starfish are said to exude a poison which diffuses through water or alcohol; when large numbers are present, the liquid may cause a pruritic rash.</p> <p><u>Chemistry, Toxicology.</u> Nature of toxin unknown. Extracts injected into cats produce prostration and convulsions.</p> |
| 14 | <p>SEA URCHIN STING caused by contact. Venom is injected by globiferous pedicellariae which are comprised of three spoon-shaped blades, each having a globular body and hook-like process. Venom glands are located under each of the blades.</p> <p><u>Animal, Distribution.</u> Sea urchins: (<i>Toxopneustes pileolus</i>), Malaya, Japan; (<i>Sphaerechinus granularis</i>), Mediterranean Sea, eastern Atlantic.²</p> <p><u>Symptoms, Findings.</u> Pedicellariae wounds produce severe pain, faintness, giddiness, dyspnea, paralysis of lips and tongue, relaxation of limbs. Drop in body temperature is usual in animals. Facial paralysis may persist 6 hr. Total paralysis and death from drowning reported.</p> <p><u>Chemistry, Toxicology.</u> Toxin resistant to high temperatures and evokes curare-like action. Depressed body temperature in animals. Exact nature of toxin unknown.</p> |
| 15 | <p>SEA CUCUMBER POISONING caused by contact.</p> <p><u>Animal, Distribution.</u> Sea cucumbers: (<i>Actinopyga agassizi</i>), British W. Indies; (<i>Holothuria argus</i>), Netherlands Indies, Australia, Polynesia; (<i>H. forskali</i>), Mediterranean Sea, southern coast of England.</p> <p><u>Symptoms, Findings.</u> Injection of extracts kills mice; when added to water extracts kill fish. Contact with organ of Cuvier may produce inflammation of skin, intense pain, and loss of sight.</p> <p><u>Chemistry, Toxicology.</u> Active toxic agent holothurin, located in the organ of Cuvier, water soluble, non-volatile, and heat stable; decolorizes Lugol's solution but not methylene blue; cannot be extracted or inactivated with acetone, ether or chloroform. One ounce of crude extract per 750 gallons of water kills fish in 23 min. Intraperitoneal injection lethal to mice.</p> |
| Chordata | |
| 16 | <p>ELASMOBRANCH POISONING caused by ingestion.</p> <p><u>Animal, Distribution.</u> Cow shark (<i>Hexanchus griseus</i>), Atlantic and Pacific Oceans, Mediterranean Sea; cat shark (<i>Scyliorhinus caniculus</i>), Atlantic Ocean, Mediterranean Sea; smooth dogfish (<i>Mustelus canis</i>), Atlantic Ocean, Caribbean Sea; requiem or blue shark (<i>Prionace glauca</i>), warm and temperate seas; Greenland shark (<i>Somniosus microcephalus</i>), North Sea, North Atlantic Ocean; skate (<i>Raja batia</i>), S. Africa, Atlantic Ocean.</p> <p><u>Symptoms, Findings.</u> Onset may occur within $\frac{1}{2}$-1 hr. Nausea, vomiting, abdominal pain, oily stools, pallor, headache, burning and tingling sensation of lips, tongue and throat, visual disturbances, pain and heaviness in limbs, chest pain, and itching; primary shock reported. Coma and death may occur several days after ingestion.</p> <p><u>Chemistry, Toxicology.</u> Artificial immunity to Greenland shark; its poison water soluble and resistant to cooking temperatures (less than 100°C).</p> |
| 17 | <p>BULLHEAD SHARK STING caused by contact. Venom secreted by the glandular epithelium in the posterior groove of the dorsal spines.</p> <p><u>Animal, Distribution.</u> Bullhead sharks: (<i>Heterodontus francisci</i>), California coast; (<i>H. philippi</i>), Australia, Japan.³</p> <p><u>Symptoms, Findings.</u> Intense pain, redness, edema, increase skin temperature.</p> <p><u>Chemistry, Toxicology.</u> Not known.</p> |
| 18 | <p>STINGRAY STING caused by contact. Venom apparatus of a bilaterally serrated, dentinal caudal spine enveloped in an integumentary sheath. Venom contained within tissues of the two ventrolateral grooves.</p> <p><u>Animal, Distribution.</u> Common stingray (<i>Dasyatis pastinacus</i>), European coasts; round stingray (<i>Urobatis halleri</i>), Pacific coast of southern N. America; spotted stingray (<i>Aetobatis narinari</i>), tropical Pacific, Atlantic and Indian Oceans.</p> <p><u>Symptoms, Findings.</u> Sting followed by intense pain often involving entire affected extremity. Wound edges ragged, localized discoloration and edema. Primary shock common; convulsions and paresthesia reported; death infrequent.</p> <p><u>Chemistry, Toxicology.</u> Action of crude extract on peripheral vascular system may be diphasic, the principal response being vasoconstriction. Large doses provoke auricular and ventricular standstill; may damage sino-auricular node. Chemical properties unknown.</p> |
| 19 | <p>RATFISH STING caused by contact. Venom secreted by epithelium of the integumentary sheath of the dorsal spine. Greatest concentration of venom tissue in the interdental depression on posterior aspect of spine.</p> <p><u>Animal, Distribution.</u> Ratfish (<i>Chimaera monstrosa</i>), Atlantic Ocean off Portugal and northern U.S.; Pacific ratfish (<i>Hydrolagus colliiei</i>), Pacific coast of N. America.</p> <p><u>Symptoms, Findings.</u> Intense pain and deaths reported for <i>Chimaera</i>. Erythema and mild, dull ache lasting several minutes reported for <i>Hydrolagus</i>.</p> <p><u>Chemistry, Toxicology.</u> One ml of crude extract kills mice in 24-54 hr.</p> |
| 20 | <p>TETRAODON POISONING caused by ingestion.</p> <p><u>Animal, Distribution.</u> Sharp-nosed puffer (<i>Canthigaster margaritatus</i>), Red Sea, E. Africa, Netherlands Indies, China, Melanesia, Micronesia, Polynesia; sharp-nosed puffer (<i>C. rivulatus</i>), Japan, Hawaiian islands; puffer (<i>Colomesus psittacus</i>), rivers of Guiana, northern Brazil, W. Indies; puffer (<i>Chilomycterus spinosus</i>), W. Indies, Brazil, S. Africa; puffer (<i>Diodon holacanthus</i>), tropical Pacific, Atlantic and Indian Oceans; tetradon of the Cape (<i>Amblyrhynchotes honckenii</i>), S. Africa, Indo-Pacific; puffer (<i>Fugu basilevskianus</i>), northern China, northwestern Korea; puffer (<i>F. chrysops</i>), Pacific coast of central Japan; puffer (<i>F. niphobles</i>), Japan; puffer (<i>F. ocellatus</i>), China, Japan, Philippine Islands; puffer (<i>F. pardalis</i>), China, Japan; puffer (<i>F. pseudomus</i>), East China Sea and Yellow Sea; puffer (<i>F. rubripes</i>), China to Korea, Sea of Japan, Pacific coast of Japan; puffer (<i>F. stictonotus</i>), southern Korea, East China Sea, Japan; puffer (<i>F. vermicularis</i>), East China Sea, Japan; puffer (<i>F. xanthopterus</i>), China, Korea, southern Japan; puffer (<i>Lagocephalus laevigatus inermis</i>), eastern Africa, tropical Indian Ocean, Australia, East China Sea, southern Japan; puffer (<i>L. lunaris</i>), Red Sea, southern and eastern Africa, India to Australia, China, Japan; puffer (<i>L. scleratus</i>), east coast Africa to Philippine Islands, southern Japan, Australia, Tahiti; puffer (<i>Sphoeroides annulatus</i>), California to Peru, Galapagos Islands; puffer (<i>S. maculatus</i>), Atlantic coast, U.S. to Guiana; puffer (<i>S. spengleri</i>), Texas, Florida, W. Indies, Brazil, Canary Islands, west coast Africa; puffer (<i>Torquigener hamiltoni</i>), Australia, Melanesia, Polynesia; sunfish (<i>Mola mola</i>), temperate and tropical seas; puffer (<i>Arothron aerostaticus</i>), Red Sea, eastern Africa, Netherlands Indies, Australia, Guam, Japan, Tahiti; puffer (<i>A. hispidus</i> and <i>immaculatus</i>), Red Sea, S. Africa to southern Japan, Australia, Melanesia, Micronesia, Polynesia, Panama; puffer (<i>Tetraodon lineatus</i>), rivers of northern and western Africa.</p> <p><u>Symptoms, Findings.</u> Onset within 30 min after ingestion. Numbness of lips, tongue, fingertips and toes; nausea, vomiting, headache, dizziness, weakness, dyspnea; occasional complete paralysis and loss of speech reported; coma and death may occur within 1-24 hr as a result of respiratory paralysis.</p> <p><u>Chemistry, Toxicology.</u> Postulated formula for tetradotoxin: $C_{16}H_{31}NO_{16}$; soluble in water; MLD for rabbits is 3.0-4.0 g/kg. Spheroidine: $C_{12}H_{17}O_{10}N_3$; insoluble in water; MLD for mice, 0.013-0.014 μg. Only a few Japanese puffers studied. It is assumed that all puffers contain same toxin.</p> |

/1/ Common sand crab (*Emerita analoga*), Pacific coast, Oregon to Mexico; contains paralytic shellfish poison varying in toxicity, depending on nearby mussels. /2/ Also sea urchins: (*Asthenosoma varium*, *Diadema antillarum*, *D. setosum*, *Echinothrix* spp., *Echinus actus*, *Paracentrotus lividus*, *Salmacis sphaeroides*); toxin in spines; nature unknown. /3/ Also DOGFISH STING. Spiny dogfish (*Squalus acanthias*), temperate waters of N. and S. hemispheres.

Chordata (concluded)

21. **CIGUATERA POISONING** caused by ingestion.
Animal, Distribution. Surgeonfish (*Acanthurus triostegus*), tropical Pacific; ladyfish (*Albula vulpes*), tropical Pacific; left-eyed flounder (*Bothus mancus*), tropical Pacific; pompano (*Caranx latus*), W. Indies, South Africa, Australia; pompano (*C. melampygus*), Red Sea, Indian Ocean, central Pacific; herring (*Clupanodon trissa*), W. Indies, Indian Ocean, Japan; anchovy (*Engraulis japonica*), Japan; wrasse (*Epibulus insidiator*), tropical Pacific; wrasse (*Cheilinus fasciatus*), Red Sea to tropical Pacific, Japan; snapper (*Lutjanus vaigiensis*), Indian Ocean and tropical Pacific; snapper (*L. bohar*), Red Sea, Indian Ocean, tropical Pacific, Japan; goatfish (*Mulloidichthys samoensis*), tropical Pacific; damselfish (*Abudefduf sexfasciatus*), tropical Pacific; parrot fish (*Scarus microrhinos*), Indian Ocean, tropical Pacific; bass (*Epinephelus fuscoguttatus*), Red Sea, Indian Ocean, tropical Pacific; bass (*Variola louti*), Red Sea, Indian Ocean, tropical Pacific; squaretail (*Tetragonurus cuvieri*), Mediterranean Sea, Atlantic and Pacific Oceans.
Symptoms, Findings. Onset may be immediate but usually within 30 hr. Tingling, numbness, malaise, chills, fever, headache, sweating, pruritus diarrhea, prostration, metallic taste, generalized motor incoordination, weakness and myalgia common. Sensory disturbances (perversion of heat and cold): convulsions and paralysis reported. About 2-3% of cases fatal. Complete recovery may take months.
Chemistry, Toxicology. Not known.
22. **GYMNOTHORAX POISONING** caused by ingestion.
Animal, Distribution. Moray eels: (*Gymnothorax eurostus*, *G. flavimarginatus*, *G. javanicus*, *G. meleagris*, *G. pictus*, *G. petelli*, *G. undulatus*), Red Sea, Indian Ocean, tropical Pacific.
Symptoms, Findings. Onset 20 min to 8 hr with tingling, numbness, vomiting, respiratory distress, laryngeal spasm and paralysis, motor incoordination, clonic and tonic convulsions; abnormal deep and superficial reflexes reported. Coma may develop, lasting 2-10 da; mortality about 10%. Acute symptoms usually subside within 10 da.
Chemistry, Toxicology. May be small molecular substance. One ml of crude extract injected intraperitoneally into mice produces death in 16 min to 24 hr.
23. **SCOMBROID POISONING** caused by ingestion.
Animal, Distribution. Mackerel (*Scomber japonicus*), Pacific, Atlantic, Indian Oceans, Mediterranean and Red Seas; skipjack (*Katsuwonus pelamis*), cosmopolitan; tuna (*Thunnus thynnus*); cosmopolitan.
Symptoms, Findings. Histamine-like symptoms: headache, flushing, congestion of soft tissues of eyes, nausea, vomiting, urticaria, and erythema. Recovery within 12 hr.
Chemistry, Toxicology. Thought to be histamine or histamine-like substance. Exact mechanism of production and chemical structure unknown.
24. **SCORPION FISH STING** caused by contact. Venom apparatus of the dorsal, ventral and anal stings. Primary sites of venom production in the glandular grooves of the stings.
Animal, Distribution. Bullroar (*Notesthes robusta*), Australia; thread-finned zebrafish (*Pterois antennata*), all tropical and temperate seas; tiger fish (*P. lunulata*), Japan, Banks Islands; zebrafish (*P. volitans*), E. Africa to Australia, Japan; lionfish (*Scorpaena grandicornis*), all seas; hogfish (*S. porcus*), Mediterranean Sea, Atlantic Ocean; scorpion fish (*S. scrofa*), Mediterranean Sea, Atlantic Ocean; lumpfish (*Inimicus didactylus*), Philippines, Malaya, Johore Straits; stonefish (*I. japonicus*), Sea of Japan, China Sea; stonefish (*Minous monodactylus*), South Seas, China, Japan; stonefish (*Synanceia horrida*), Red Sea, coasts of Africa, India, Malaya, Indo-Pacific, Australia, New Zealand; stonefish (*S. verrucosa*), Red Sea, coasts of Africa and India, Netherlands Indies, Australia, tropical Indo-Pacific, Marshalls, Polynesia.
Symptoms, Findings. Localized pain, pallor about wound, diarrhea, vomiting. Dyspnea, coma and fatalities reported.
Chemistry, Toxicology. Not known.
25. **WEEVERFISH STING** caused by contact. Venom apparatus of opercular and dorsal stings. Venom gland located within glandular grooves of the sting.
Animal, Distribution. Weever (*Trachinus draco*), European seas, Australia, Chilean seas; (*T. radiatus*), Mediterranean Sea; (*T. vipera*), European seas.
Symptoms, Findings. Intense shooting pain, redness and edema of affected part, vomiting, diuresis and diarrhea.
Chemistry, Toxicology. Two or three drops of venom injected intravenously into rabbit produce death in 4-10 min. Venom thought to contain both neurotoxic and hemotoxic fractions.
26. **TOADFISH STING** caused by contact. Venom apparatus of the opercular and dorsal stings. Venom produced by sac-like glands at base of stings.
Animal, Distribution. Grunting toadfish (*Batrachus grunniens*), W. Indies, tropical waters; toadfish (*Opsanus tau*), waters of N. America; toadfish (*Thalassophryne dowi*), Pacific coast of Panama, tropical and south temperate America; toadfish (*T. maculosa*), east coast of America; lumpfish (*T. reticulata*) Panama, Brazil.
Symptoms, Findings. Severe localized pain; convulsions reported. Seldom serious.
Chemistry, Toxicology. Not known.
27. **CATFISH STING** caused by contact. Venom apparatus of dorsal and pectoral stings, and axillary venom glands. Venom glands in the integumentary sheaths surrounding the spines. Axillary gland located under skin beneath posthumeral process of cleithrum and opens to outside by pore.
Animal, Distribution. Madtoms (*Noturus* spp), rivers of N. and S. America; Madtoms (*Schilbeodes* spp), rivers of N. and S. America; sea catfish (*Galeichthys felis*), coasts of southeastern U.S.; (*Heteropneustes fossilis*), India, Burma, Ceylon, Indo-China, swamps, marshes, muddy rivers; (*Ictalurus catus*), rivers of northeastern America, Italy; (*Plotosus lineatus*), throughout Indo-Pacific region.
Symptom, Findings. Stinging pain either localized or radiating through limb, usually subsides within 30 min. Area becomes ischemic, redness and edema may follow. In severe cases massive edema and numbness involving entire limb often accompanied by lymphadenopathy. Primary shock reported. Recovery may take weeks.
Chemistry, Toxicology. Not known.
28. **SURGEONFISH STING** caused by contact. Caudal penduncular spine inflicts wound.
Animal, Distribution. Surgeonfish, lancet fish (*Acanthurus hepatus*), Atlantic Ocean to W. Indies.
Symptoms, Findings. Sharp pain which may last several hours.
Chemistry, Toxicology. Not known.
29. **DRAGONET STING** caused by contact. Venom apparatus of venom glands in connection with spines. (See Weeverfish.)
Animal, Distribution. Dragonet (*Callionymus lyra*), coast of France, tropical zones.
Symptoms, Findings. Sharp stinging pain.
Chemistry, Toxicology. Not known.
30. **TURTLE POISONING** caused by ingestion.
Animal, Distribution. Hawksbill sea turtle (*Eretmochelys imbricata*), Arabia, Malay Peninsula and Archipelago, Australia, Formosa, Samoa, Guiana, Bahamas, Guatemala; hawksbill (*Chelonia japonica*) Philippines; leatherback (*Dermochelys coriacea*), Cape of Good Hope, Indian Ocean, New Zealand, Solomons.
Symptoms, Findings. Onset almost immediate to one week, with nausea, vomiting, diarrhea, weakness and sore lips and throat. Hallucinations, coma and death may occur within 12 hr after ingestion.
Chemistry, Toxicology. Not known.
31. **PORPOISE POISONING** caused by ingestion.
Animal, Distribution. Porpoise (unidentified sp), Yangtze region of China, Chinese rivers. Not poisonous in open seas.
Symptoms, Findings. Onset almost immediate. Severe pain, numbness and paralysis of extremities, cyanosis, swelling of abdomen, salivation, and rapid death. Many fatal cases reported, especially in spring. Blood, liver, fat and eyes are reported most toxic.
Chemistry, Toxicology. Not known.

359. TOXIC PLANTS

Plant [Toxic Portion] Geographic Distribution	Toxic Principle	Signs and Symptoms Produced	Remarks
1 Amanita, deadly (Amanita phalloides) [Entire fungus] Europe, N. America	Amanita-toxin (amanitin) formerly reported as phallin. Fungus also contains amanita-hemolysin, possibly a factor in poisoning by the raw mushroom.	After 6-15 hr: Abdominal pain; vomiting; diarrhea; intense thirst; recurrent drowsiness; respiratory, circulatory depression; delirium; sometimes convulsions; jaundice, hepatitis; renal disturbances; coma; death from heart failure.	One of the most deadly of fungi with a mortality of about 50%; cause of 90% of "mushroom deaths" in U.S. Genus contains other equally poisonous mushrooms and some edible species.
2 Autumn crocus (Colchicum autumnale) [Entire plant; principally corms, seeds] U.S., England, Europe, N. Africa	Colchicine.	Man: Burning in throat; 6-8 hr later a feeling of suffocation, oppression in chest, difficult swallowing; vomiting; diarrhea; colic; tenesmus; giddiness; weakness in legs; arthralgia; cyanosis; labored breathing; convulsions; death from respiratory exhaustion in 7-36 hr; consciousness preserved to end. Other animals: Nausea; vomiting; colic; diarrhea; hematuria; depression; unconsciousness; paralysis; mydriasis; profuse perspiration. Death in 1-3 days.	Colchicine arrests mitotic division of cells. Effects in relief of gout may be dramatic.
3 Belladonna ¹ (Atropa belladonna) [Entire plant; especially seeds, roots, leaves] Europe, Asia, eastern U.S.	Chiefly hyoscyamine, atropine, other solanaceous alkaloids.	Man, acute: Dryness of skin, mouth, throat; difficulty in swallowing; flushing of face; cyanosis; mydriasis; nausea; vomiting; constipation. Slurred speech; giddiness; stupor; coma; rapid, weak pulse; fever; death from asphyxia, heart failure. Man, chronic: Erythema, urticaria, vesicular eruptions; slurred speech; mydriasis; glaucoma; muscular tremors or twitchings. Sudden withdrawal causes nausea, salivation, perspiration. Cattle: Mydriasis; constipation; rapid pulse; labored breathing; frenzy; paralysis.	Yields belladonna preparations. Fruits most often responsible for poisoning in man.
4 Castor bean (Ricinus communis) [Seeds] Primarily tropical Africa; U.S., tropics and subtropics	Ricin or phyto-toxin; ricinine.	Man: Burning in mouth, throat and stomach; vomiting; diarrhea; thirst; rapid, then faint pulse; cramps of abdomen, legs; convulsions; shallow respirations. Other animals: Hemorrhagic enteritis; staggering; dulled vision; heart weakness; bloating; paralysis; convulsions; fever; shivering; coma; death in 1-3 days.	Seeds yield castor oil. 2 or 3 seeds may be fatal to child. Ricin not extracted in oil.
5 Chinaberry (Melia azedarach) [Fruit (pulp only), bark, flowers] S.W. Asia, South Africa, tropical America, southern U.S.	Azadarin (margosine), possibly an alkaloid, affecting central nervous system.	Man: Leaf poisoning produces stomatitis; decrease in urine formation; violent, bloody vomiting. Fruit poisoning results in irregular breathing, signs of suffocation; complete paralysis. Other animals (especially swine): Vomiting; colic; diarrhea; labored breathing; convulsions or paralysis; death by asphyxia.	Roots, bark, leaves, flowers and fruit used for stupefying fish. Seeds yield oil of azedarach.
6 Chokecherry and other wild cherries (Prunus spp) [Leaves, especially when wilted; bark, seeds] Primarily northern hemisphere; Orient	Hydrocyanic acid is formed by action of enzymes upon amygdalin (?) or prunasin.	Animals: Uneasiness; staggering; falling; convulsions; labored breathing; bloating; death.	Frequent cause of fatal poisoning of livestock.
7 Christmas rose (Helleborus niger) [Rootstock, leaves] Primarily Europe	Helleborin, helleborein, hellebrin.	Man, externally: Severe dermatitis in some individuals. Man, internally: Violent inflammation of mucous membranes of stomach, intestines; vomiting; dizziness; convulsions; sometimes death. Digitalis-like effect on heart.	Cultivated in flower gardens. Rootstock formerly an official drug.
8 Coca (Erythroxylum coca) [Leaves] Northern S. America; tropics of both hemispheres	Cocaine, other alkaloids.	General central nervous system stimulation followed by depression; numbness of tongue, paralysis of respiratory centers; cyanosis; shallow, irregular breathing; often sudden death from asphyxia.	Leaves commonly chewed as a stimulant by Indians of Peru and Bolivia. Cocaine used as a local anesthetic.
9 Corn-cockle (Agrostemma githago) [Seeds] Europe, Canada, U.S.	Githagin, agrostemmic acid (saponins).	Man: Irritation of digestive tract; vomiting; headache; vertigo, diarrhea; depressed breathing; sharp pains in spine; difficult locomotion; sometimes coma, death. Horses and cattle: Colic; diarrhea; muscular tremors; rigidity; coma, death. 0.25-1 lb per 100 lb live weight fatal.	Milled seeds sometimes present in wheat flour. Frequent ingestion of small amounts results in chronic githagism.
10 Croton, purging (Croton tiglium) [Roots, leaves, bark, seeds] Southern Asia, East Indies, Pacific Islands, Africa	Croton, croton resin.	Externally: Croton oil is a skin-irritant, causing reddening, swelling, pustules. Smoke from burning wood inflames the eyes. Internally: Vomiting, drastic purging; possibly collapse and death.	Yields croton oil, formerly a human and veterinary purgative, lubricant for fine machinery.
11 Curare (Strychnos toxifera) [Bark, roots; not extremely toxic by mouth] Central America, northern S. America	Tertiary bases: curine, n-chondrocurine, p-isochondrodendrine, and p-isochondrodendrine dimethylether. Quaternary salts: n-tubocurarine chloride, p-chondrocurine dimethiodide, and n-tubocurarine chloride and others.	Haziness of vision; relaxation of facial muscles; inability to raise head; loss of muscular contraction in arm and leg; depressant effects on the muscles of respiration; muscle nerve end-plate paralysis.	Source of curare, one of the most potent poisons known. Tubocurarine chloride (U.S.P.) now used as a skeletal muscle relaxant in shock therapy, and as a diagnostic aid.
12 Death camass (Zigadenus spp) [Leaves, stems, flowers, bulb] Northern hemisphere, especially western U.S.	Zygadenine, similar to veratrine and cevadine in action.	Animals: Salivation; vomiting; lowered temperature; staggering or collapse; labored breathing; paralysis; possibly coma, death.	Frequent cause of fatal poisoning of livestock. Children occasionally poisoned by eating bulb.

^{1/} Henbane (Hyoscyamus niger), which yields scopolamine, hyoscyamine, atropine, and other alkaloids, has similar signs and symptoms.

359. TOXIC PLANTS (Continued)

Plant [Toxic Portion] Geographic Distribution	Toxic Principle	Signs and Symptoms Produced	Remarks
13 Ergot (<i>Claviceps purpurea</i>) [Sclerotium] Europe, Asia, Australia, N. America	Ergotoxine, ergotamine, ergonovine, and others.	Man, acute: Vomiting; diarrhea; respiratory difficulties; visual, motor disturbances; followed by convulsions, lowered blood pressure, shallow respiration, unconsciousness. In pregnancy, possibly uterine hemorrhage, abortion, peripheral gangrene. Man, chronic: Convulsive type -- vomiting; itching; paresthesia; analgesia of extremities; anorexia or uncontrollable hunger; diarrhea; muscle contracture; delirium; sometimes a tabes-like complex. Gangrenous type -- pustules may form; limbs swell, become hot; gangrene may follow. Cattle: Gastrointestinal irritation; gangrene of extremities; uterine contractions; nervous disturbances.	Occurs on wheat, oats, barley, rye, and other grasses; cause of many cases of poisoning (ergotism) in man and livestock.
14 Foxglove (<i>Digitalis purpurea</i> , <i>D. lanata</i>) [Entire plant, especially seeds, leaves] From western Europe; widely distributed.	Diacetyldigilanol A and B in <i>D. purpurea</i> . Digilanol A, B, C, in <i>D. lanata</i> .	Anorexia; nausea; vomiting; slow, pronounced pulse in early stages; cardiac arrhythmias; diarrhea; abdominal pain; headache; fatigue; drowsiness; convulsions; rapid, irregular pulse; death in severe cases.	Digitalis and derivatives used in cardiovascular therapy. <i>D. purpurea</i> common in flower gardens.
15 Grass-pea (<i>Lathyrus sativus</i>) [Seeds, mature plant] Southern Europe, Asia, southern U.S.	Alkaloids.	Man: Sudden weakness in legs from effect on spinal cord. Further ingestion may cause leg paralysis. Animals: Similar, plus asphyxia. Cattle evidence constipation, weak pulse, numbness of skin.	Used as food and fodder but causes many cases of lathyrism in man and livestock.
16 Groundsel (<i>Senecio</i> spp) [Entire plant, especially seeds] World-wide.	Senecifoline, senecifolidine, retorsine, seneciphylline, jacobine.	Man: Abdominal pain; vomiting; ascites; enlarged liver; emaciation; bloody diarrhea. Generally fatal in the absence of early treatment. If not immediately fatal, liver damage may bring about subsequent death. Grazing animals: Inappetence; emaciation; staggering; colic; unconsciousness; death.	Seeds of various species in harvested grain considered responsible for "bread poisoning." <i>Senecio</i> poisoning common in livestock.
17 Hellebore, American white (<i>Veratrum viride</i>) [Entire plant] Canada, U.S.	Protoveratrine, germerine, jervine, and others.	Man: Vomiting; abdominal pain; muscular weakness; spasms; possibly convulsions; rapid pulse; shallow breathing; semi-consciousness; death from asphyxia.	This and related species yield veratrum, a therapeutic agent for hypertension.
18 Hemp, marijuana (<i>Cannabis sativa</i>) [Upper leaves, flower bracts of female plants] Temp. Asia, Europe, U.S., Mexico, Panama	Cannabinene, tenanocannabinene, cannabinol.	Man: Exaltation; inebriety; confusion; followed by central nervous system depression. Prolonged addiction may produce dullness or mania; in rare cases death from cardiac depression.	Dried leaves and bracts smoked by marijuana addicts; seeds harmless.
19 Larkspur (<i>Delphinium</i> spp) [Seeds, leaves; to a lesser degree, roots] North temperate regions, including western U.S.	Delphinine, delphinoidine, delphisine, staphisagrine.	Man: Burning, inflammation of mouth and pharynx; lowered blood pressure; nausea; abdominal pain; labored respiration; itching; cyanosis. Animals: Inappetence; uneasiness; staggering; constipation; nausea; bloating.	Second to locoweed (q.v.) in causing fatalities among livestock.
20 Lead-tree (<i>Leucaena glauca</i>) [Leaves (especially immature), bark, roots] Southern U.S., tropics	Mimosine (leucenol).	Horses, mules and donkeys: Alopecia of manes and tails; possibly deformation, loss of hoofs. Swine: Total alopecia; impaired vision; emaciation; various degrees of paralysis; respiratory failure.	A fodder plant for cattle, sheep, goats (immune to toxic action). Seeds used as coffee substitute.
21 Locoweed (<i>Astragalus</i> spp) [Fresh plant] Northern hemisphere	Selenium; locoine in some species.	Horses and cattle: Dullness; weakness; irregularity in behavior; impaired vision; edema of eyelids; loss of muscular control; depraved appetite; emaciation; starvation; death. Sheep: Above symptoms, with possibly blindness.	Hazard to livestock industry of the U.S.; toxicity varies with locality.
22 Lupine (<i>Lupinus</i> spp) [Pods, leaves; especially seeds] Temperate regions.	European spp: Ictrogen (lupinotoxin); American spp: sparteine (lupinidine), lupinine.	European lupinosis, chronic: Anemia; cachexia. Acute: Fever; general icterus; coma; paralysis; constipation followed by hemorrhagic diarrhea; swelling of ears, eyelids, lips, nose. American lupinosis, sheep: Frothing at mouth; dyspnea; frenzied actions; nausea; bloating; coma, possibly death.	Toxicity of lupines varies with season and location; some species are harmless. Many livestock fatalities in Europe and U.S. attributed to lupines.
23 Manchineel (<i>Hippomane mancinella</i>) [Milky sap] Florida, W. Indies, Central America, northern S. America	Physostigmine or a similar alkaloid, plus a sapogenin.	Man, externally: Severe burning of skin, swelling; possibly hemorrhage in eyes; temporary blindness from sap. Man, internally: Fruit causes gastroenteritis which may be fatal. Ulceration of intestinal tract proceeds slowly.	Apparently more toxic in summer than in winter. Sap used as arrow poison. Smoke from burning wood toxic.
24 Manioc (<i>Manihot esculenta</i>) [Roots; mature leaves, stems, fruit] Tropics	Phaseolunatin	Man and livestock: Rapid, labored breathing; rapid, irregular, weak pulse; twitching; staggering; spasms of neck, legs; convulsions; mydriasis; coma; death from respiratory paralysis.	Cultivated for starch from which tapioca is made.
25 Metel (<i>Datura metel</i>) [Entire plant] India; tropics	Scopolamine, hyoscyamine, atropine.	Man: Mydriasis; drowsiness; thirst; bitter burning sensation in mouth; impaired vision; delirium. Exhaustion, coma, death, in extreme cases. Non-fatal poisoning usually results in loss of memory, mental confusion.	Used medicinally in Far East; employed criminally for narcotic effect on victims.
26 Monkshood (<i>Aconitum napellus</i>) [Roots, leaves, flowers, seeds] Europe, Asia, Canada, northeastern U.S.	Aconitine, picroaconitine, aconine, napelline, and others.	Moderate doses: Tingling, burning sensation in tongue, throat, skin; great restlessness; dyspnea; slow pulse; muscular weakness; incoordination; cold, livid skin; pupillary constriction, followed by dilation; vomiting; diarrhea; convulsions; possibly death in 1-8 hr by respiratory or cardiac paralysis.	Young leaves have been eaten by mistake for parsley and the roots for horseradish.
27 Mountain-laurel (<i>Kalmia latifolia</i>) Sheep-laurel (<i>K. angustifolia</i>) [Entire plant, except wood] Canada, northeastern U.S., Pacific Coast	Andromedotoxin.	Animals (usually sheep): Salivation; flow of tears; secretions from nose; frothing at mouth; impaired vision or blindness; dizziness; irregular respiration; vomiting; convulsions, followed by paralysis of limbs, coma, death. Man: Similar to above, plus pain in head, sweating, tingling of skin.	Frequent cause of fatal poisoning of livestock, especially sheep.

359. TOXIC PLANTS (Concluded)

Plant [Toxic Portion] Geographic Distribution	Toxic Principle	Signs and Symptoms Produced	Remarks
28 Nightshade, black (<i>Solanum nigrum</i>) [Entire plant, unripe fruit] World-wide	Solanine, saponin.	Man: Vomiting; diarrhea; rapid pulse; fever; sweating; dizziness; mydriasis; disturbed speech, sight; hallucinations. Death from heart failure or respiratory paralysis. Other animals: Nervous form -- narcosis; paralysis. Gastric form -- salivation; vomiting; bloating; diarrhea. Exanthematous form -- vesicular exanthema on legs, udder, scrotum, neck; conjunctivitis.	
29 Oleander (<i>Nerium oleander</i>) [Leaves, bark, roots, flowers] Tropics, subtropics	Nerolin, oleandrin.	Man: Vomiting; slow, irregular pulse; bloody diarrhea; death from cardiac or respiratory paralysis. Other animals: Similar to above, plus sweating, gnashing of teeth, groaning, sometimes polyuria.	Smoke from burning green plants can cause poisoning. Meat roasted on skewers of oleander wood, or food stirred with oleander sticks, becomes fatally poisonous. Honey made from the nectar possibly toxic.
30 Physic nut (<i>Jatropha curcas</i>) [Seeds, milky sap] Tropics	Curcin.	Man: Burning in throat; bloating; dizziness; vomiting; diarrhea; drowsiness; possibly dysuria, mydriasis; severe leg cramps; deafness. Violent purgative action often fatal to children. Other animals: Hemorrhagic enteritis; staggering; dull vision; mydriasis; bloating; paralysis; somnolence; convulsions; fever; shivering; coma; death in 1-3 days in acute cases.	Sap used as a fish poison.
31 Poison hemlock (<i>Conium maculatum</i>) [Fruit; stems, leaves, root] Europe, Asia, Africa, N. America	Coniine, conhydrine, methylconiine, coniceine.	Man: Muscular weakness; often blindness; paralysis of extrem- ities; death from respiratory paralysis. Cattle: Inappetence; salivation; bloating; muscular weakness; coma. Horses: Nausea; grinding of teeth; rapid, labored respiration; paralysis; death from respiratory failure.	Leaves more toxic when plant is flowering; root less toxic in spring.
32 Poison ivy (<i>Rhus toxicodendron</i>) ² [Entire plant] N. America	Urushiol, toxico- dendrol, or toxicodendrin.	Man: Skin irritation, swelling, blisters, extreme discomfort. Sometimes fatal to children.	Smoke from burning plant toxic.
33 Poison wood (<i>Metopium toxiferum</i>) [Entire plant, especially sap] Southern Florida, W. Indies	Probably similar to poison ivy.	Externally: Dermatitis similar to that caused by poison ivy. Blistering may continue for weeks, readily spreading from one area to another; may be accompanied by intense itching, burning.	Smoke from burning wood highly irritating.
34 Pokeweed (<i>Phytolaca americana</i>) [Entire plant, especial- ly root] Eastern and southern U.S.	Saponin and a toxic resin-like material.	Vomiting; purging; spasms, sometimes convulsions; death from respiratory paralysis.	Young shoots edible if well cooked.
35 Spurge (<i>Euphorbia</i> spp) [Milky sap] World-wide	Euphorbon, euphorbor- esene, and an acid substance.	Man, externally: Dermatitis; eye-irritation, temporary blind- ness. Man, internally: Swelling around mouth, eyes; burning in mouth, throat; sneezing; vomiting; diarrhea; fainting; death. Other animals, externally: Blistering of skin, loss of hair. Other animals, internally: Weakness; collapse; scours; death.	Euphorbium derived from <i>E.</i> resinifera formerly used medicinally, now employed in paint as a protectant. Severe dermatitis observed from sap of poinsettia (<i>E.</i> pulcherrima).
36 Strophanthus (<i>Strophanthus</i> spp) [Seeds, bark] Tropical Africa, southern Florida, tropical America	Strophanthin.	Vomiting; slow, irregular pulse; blurred vision; delirium; death from circulatory failure of cardiac origin. Effect on heart similar to that of digitalis.	Arrow-poisons from several species. <i>S. sarmentosus</i> is a possible source of cortisone.
37 Strychnine tree (<i>Strychnos nux-vomica</i>) [Seeds, leaves, bark, wood, flowers] India, Hawaii	Strychnine, brucine.	Action on spinal cord causes excessive reflex irritability, followed by rapid tonic convulsions with intermissions of ex- haustion and sweating; extreme muscular rigidity, asphyxia; death. Mind not affected.	Strychnine formerly used as stimulant and tonic.
38 Thevetia (<i>Thevetia peruviana</i>) [Leaves, seeds, bark, milky sap] Tropics	Thevetin.	Externally: Contact with sap may inflame and blister skin. Internally: Vomiting; high blood pressure; erratic heart beat; death from asphyxiation, sudden cardiac paralysis.	Seeds used as fish poison.
39 Thorn apple (cocklebur) (<i>Datura stramonium</i>) [Entire plant (including flowers, nectar), especially seeds] Tropics; N. America	Scopolamine, hyoscyamine, atropine.	Man: Headache; nausea; vertigo; thirst; dry, burning sensation in skin; mydriasis; loss of muscular control. Acute poisoning results in mania, convulsions, death. Cattle: Mydriasis; suspension of secretions or diarrhea; rapid heart action; paralysis; death from asphyxia. 10-15 oz of plant fatal. Swine: Convulsive twitching.	Children often poisoned by eating seeds and pods.
40 Upas tree (<i>Antiaris toxicaria</i>) [Milky sap] Southern Asia, E. Indies	Antiarin (α -, β -)	Externally: Skin irritation, blistering, swelling. Internally: Vomiting; convulsions; death. [E. Indies, southern Asia] Cloth made from the bark causes intolerable itching if sap (latex) is not thoroughly eliminated. More potent than digitalis in effect on heart.	One of the principal arrow- poisons of natives of [E. Indies, southern Asia]
41 Water hemlock (<i>Cicuta maculata</i> and related spp) [Primarily roots] North temperate regions	Cicutoxin.	Man and other animals: Abdominal pain; nausea; vomiting; diarrhea; mydriasis; labored breathing; foaming at mouth; weak, rapid pulse; epileptoid convulsions; death from respiratory failure.	Genus includes the most poisonous plants in the U.S.
42 Wild yam (<i>Dioscorea hispida</i>) [Entire plant, tubers] Southern Asia, E. Indies, Pacific Islands	Dioscoreine.	Discomfort, then burning, in throat; giddiness; vomiting of blood; suffocation; drowsiness; exhaustion.	Eating raw tubers a frequent cause of death in Philippines.

/2/ Data applicable also to poison sumac (*R. vernix*).

360. ALKALOIDS: OCCURRENCE, PHYSICAL, CHEMICAL, AND BIOLOGICAL CHARACTERISTICS

Information regarding properties of salts is enclosed in brackets. Remarks when not bracketed may refer to alkaloids (base or B) or to salts, or to both.

Alkaloids [Salts] ¹	Botanical Source	Geographical Source	Properties ²	Solubility ²	Remarks ³
1 Aconitine C ₃₄ H ₄₉ NO ₁₁ [B·HCl·½H ₂ O]	Aconitum napellus (root).	Europe, Asia.	MP = 204; (α) _D = +17.3° in chl.	s. chl., bz., al., eth.; i.w.	One of several isomers in aconite root. Acts peripherally and centrally on nervous system; highly toxic; relieves neuralgia, toothache; depresses heart; lowers blood pressure; causes smarting, tingling of skin, prickling in throat.
2 Apomorphine C ₁₇ H ₁₇ NO ₂ [B·HCl·½H ₂ O]	Morphine.		[(α) _D = -48° in w.]	[s. w.1:50.]	B and salt oxidize readily in air. Stimulates medullary chemoreceptor trigger zone to produce emesis; CNS depressant.
3 Arecoline C ₈ H ₁₃ NO ₂ [B·HBr]	Areca catechu (nut).	Pacific islands, India, E. Africa.	BP = 209; opt. inactive; [MP = 169-171].	s.w., al., eth., chl.; [s. w.1:1].	Parasympathetic stimulant; sialogogue diaphoretic; anthelmintic.
4 Atropine (DL-Hyoscyamine) C ₁₇ H ₂₃ NO ₃ [B ₂ ·H ₂ SO ₄ ·H ₂ O]	Atropa belladonna (leaf, root), also synthetic.	Europe.	MP = 118; (α) _D = 0°; [MP = 190-194; (α) _D = 0°].	s. w. 1:455, al. 1:2, glyc., eth., bz., chl.; [s.w.1:0.4, al.1:5, sl.s.chl., eth.].	Parasympatholytic: mydriatic, speeds heart, relaxes gut, causes vasodilation, inhibits secretions; also CNS stimulant.
5 Berberine C ₂₀ H ₁₉ O ₅ N·5½H ₂ O [C ₂₀ H ₁₈ O ₄ N·HSO ₄]	Barberry (bark) (Berberis vulgaris, B. asiatica).	Europe, India, N. America.	Loses water above 100°C; d. about 160°C.	s.w., al.; sl. s. acet., bz., eth., chl.; [s.w.; sl. s. al.].	Effective against cutaneous leishmaniasis; bactericide; has very bitter taste; stimulates heart rate; excreted in urine.
6 Caffeine C ₈ H ₁₀ N ₄ O ₂ [B + Na benzoate]	Coffee (Coffea arabica), tea (Thea sinensis).	Tropical, subtropical areas.	MP = 238; opt. inactive.	s.w.1:46, al.1:66, chl.1:5.5; sl.s.eth., pet. eth.; [s.w. 1:1.1, al. 1:30].	Causes mild CNS stimulation, particularly cortex and medullary centers. Relaxes vascular musculature, stimulates heart and skeletal muscle, causes diuresis. [Contains approx. 50% caffeine.]
7 Cevadine (Veratrine) C ₃₂ H ₄₉ NO ₉	Helibore (rhizome) (Veratrum spp).	Europe, U.S.	MP = 205; (α) _D = +12.5° in al.	s. al., eth. 1:15; i.w.	Action like veratramine.
8 Cinchonidine C ₁₉ H ₂₂ N ₂ O [B ₂ ·H ₂ SO ₄]	Cinchona spp.	S. America, Java.	MP = 210; (α) _D = -109° in al.	s. al., chl.; mod. s. eth.; i.w.; [s.w.1:70].	Antimalarial, see quinine.
9 Cinchonine C ₁₉ H ₂₂ N ₂ O [B ₂ ·H ₂ SO ₄ ·2H ₂ O]	Cinchona spp.		MP approx. 265; (α) _D = +229° in al.; [MP approx. 198].	s. al.1:60, chl. 1:110; sl.s. eth.; w.; [s.w.1:65, al.1:12].	Antimalarial, see quinine.
10 Cocaine C ₁₇ H ₂₁ NO ₄ [B·HCl]	Erythroxylum coca (leaf).	S. America, Java.	MP = 98; (α) _D = -16° in chl.; [MP approx 195; (α) _D = -72° in w.].	s. w. 1:600, al. 1:65; fats v.s. chl., eth.; [v.s.w., al.; i.eth., fats].	Local anesthetic, absorbed both from mucous membrane or by injection; CNS stimulation, particularly cortex; potentiates sympathetic nervous system, causes vasoconstriction; habit-forming, but does not cause true addiction.
11 Codeine C ₁₈ H ₂₁ NO ₃ ·H ₂ O a[B ₂ ·H ₂ SO ₄ ·5H ₂ O] b[B·H ₃ PO ₄ ·½H ₂ O]	Poppy, opium (Papaver somniferum), also from morphine.	Asia Minor, India.	MP = 155; (α) _D = -136° in al.; (α) _D = -112° in chl.; a[(α) _D = -101° in w.].	s.w.1:120, al.1:2, bz., chl.; i.pet. eth.; a[s.w.1:30, al. 1:1020; b[s.w.1:2.3, in chl.; al.1:325].	Narcotic, analgesic, sedative, antitussive. Less potent than morphine. Causes true addiction.
12 Colchicine C ₂₂ H ₂₅ NO ₆	Saffron (seed and corm) (Colchicum autumnale).	Europe, N. Africa.	MP = 157; (α) _D = -121° in chl.; (α) _D = -429° in w.	s. al., chl., w.1:22, bz.1:100.	Causes transient fall in number of leucocytes; appears to stimulate karyokinesis in bone marrow; arrests cell division in metaphase; causes bizarre mitotic figures; relieves acute gout.
13 Conessine C ₂₄ H ₄₀ N ₂	Conessi (bark), (Holarhena antidysenterica).	India.	MP = 125; (α) _D = -25 in al.	s. al., chl.; sl. s.w.	Local anesthetic; causes necrosis; kills Entamoeba histolytica (effective orally).
14 Conine C ₈ H ₁₇ N [B·HBr]	Poison hemlock (Conium maculatum)	Europe.	MP = -2; BP = 166; (α) _D = +16° (no solvent); [MP = 207].	s. al., eth., acet., bz.; sl.s.w.; [s.w.; al., chl., eth.].	Paralyzes motor nerve endings; first stimulates, then depresses CNS. [Has been used as sedative, antispasmodic.]
15 Emetine C ₂₉ H ₄₀ N ₂ O ₄ [B·2HCl + 3 to 8H ₂ O]	Ipecac (root) (Cephaelis ipecacuanha).	Brazil.	MP = 74; (α) _D = -50° in chl.	s. al., eth., chl.; sl.s.w., pet. eth.; [s.w. approx. 1:7].	Kills Entamoeba histolytica; toxic to heart, skeletal muscles; concentrated in liver.
16 Ephedrine C ₁₀ H ₁₅ NO·½H ₂ O a[B·HCl] b[B ₂ ·H ₂ SO ₄]	Ephedra spp, also synthetic.	China, India.	MP approx. 40; (α) _D = +11° in w.; a[MP approx. 216; (α) _D = -34° in w.]; b[d.245; (α) _D = -30° in w.].	s. al., eth., chl., oils, w.1:20; a[s.w.1:3, al. 1:14; b[s.w.1:2, al.1:95].	Sympathomimetic; stimulates CNS and heart muscle; raises blood pressure; constricts arterioles; relaxes smooth muscle of bronchi and gastrointestinal tract; dilates pupil; increases metabolic rate; readily absorbed from intestinal tract.
17 Ergonovine C ₁₉ H ₂₃ N ₃ O ₂ [B·C ₄ H ₄ O ₄ (maleate)]	Ergot (Claviceps purpurea).	Russia, Finland, Spain, Portugal, U.S. (Minnesota)	MP = 162; (α) _D = +44° in chl.; [d. 167; (α) _D = +48° to +57° in w.].	s. al., acet., eth. ac.; mod. s.w.; [s.w.1:36, al.1:120].	Stimulates uterus, causing rapid contraction; absorbed from GI tract.
18 Ergotamine C ₃₃ H ₃₅ N ₅ O ₅ [B ₂ ·tartrate + 2CH ₃ OH]	Ergot (C. purpurea).		d. 212-214; (α) _D -160° in chl.; [(α) _D = -125° to -155° in chl.].	s. chl., pry, me. al. 1:70, acet.1:150; [s.w., al. 1:500].	B usually cryst. solvated, e.g., + 2 acet. + 2H ₂ O. Stimulates uterus; causes peripheral vasoconstriction; causes adrenergic blockage; stimulates and depresses CNS; depresses heart; causes vomiting.
19 β-Erythroidine C ₁₆ H ₁₉ NO ₃	Coral tree (seed) (Erythrina americana).	N. America.	MP = 100; (α) _D = +89° in w.	s.w., chl., al., bz.; mod. s. eth.	Blocks myoneural junction, causing skeletal muscle paralysis; CNS depressant; absorbed from GI tract.
20 Heroin (diamorphine) (C ₂₁ H ₂₃ NO ₅) [B·HCl·H ₂ O]	Morphine.		MP = 173; (α) _D = -166° in me. al.; [MP = 244; (α) _D = -156° in w.].	s. chl.1:1.5, al.1.31, eth.1:100; sl.s.w.; [s.w.1:2, al.1:11; eth.].	Narcotic, action similar to morphine, more potent but shorter duration. Causes euphoria and severe addiction; production illegal in most countries.
21 Hydrastine C ₂₁ H ₂₁ O ₆ N [B·HCl]	Orange-root (root) (Hydrastis canadensis).	N. America.	MP = 132; (α) _D = -50 in al.; [(α) _D = +127 in dil. HCl].	s. chl., acet., bz.; sl.s.al., eth.; [s.w., al.].	Oxytocic; internal styptic in uterine hemorrhage; stimulates spinal center; excreted unchanged in urine.
22 Hyoscyamine C ₁₇ H ₂₃ NO ₃ [B·HCl]	Solanaceae.	World-wide.	MP = 108.5; (α) _D = -21° in al.; [MP = 149-151].	s. al., chl., bz.1:150, w.1:280; [s.w., al.].	The levo-rotatory constituent of atropine. Action like that of atropine.
23 Lobeline C ₂₂ H ₂₇ NO ₂ (Lobelia inflata), also synthetic.	Indian tobacco, (Lobelia inflata), also synthetic.	N. America.	MP = 130-131; (α) _D = -43° in al.; [MP = 178-180].	s. chl., bz., hot al.; i.w.; pet. eth.; [s.w. 1:40, al. 1:12; v.s.chl.].	Action like that of nicotine, less potent.

24	Mescaline $C_{11}H_{17}NO_3$ [B·HCl]	Mescal cactus (flesh) (Anhalonium Lewinii).	Southwestern U.S., Mexico.	MP = 35-36; opt. inactive; [MP = 181].	s. al., chl., bz.; sl.s.w.; i.eth., pet. eth.; [s.w., al.].	Depresses CNS; produces psychic effects and visual color hallucinations.
25	Morphine $C_{17}H_{19}NO_3 \cdot H_2O$ a [B·HCl·3H ₂ O] b [B ₂ ·H ₂ SO ₄ ·5H ₂ O]	Opium, see codeine.		d. 254; (a) _D = -132° in me.al.; a [d. approx. 200; (a) = -111° in w.]; b [(a) _D = -95° in w.].	s.al. 1:210, chl. 1:1200, hot me.al. 1:10, alkalies; a [s.w. 1:17, al. 1:50]; b [s.w. 1:15, al. 1:565].	Narcotic action in man; produces analgesia and sleep; depresses respiration; constricts pupils; relieves pain; contracts smooth muscles; effects constipation; retards secretion of HCl by stomach; little effect on blood pressure, heart rate or rhythm; readily ab- sorbed from the GI tract; principally destroyed in body and excreted in urine. Causes true addiction.
26	Narcotine $C_{22}H_{23}NO_7$	Opium.		MP = 176; (a) _D = -207° in chl.	s.chl. 1:2, bz. 1:30, al. 1:250; sl.s. hot w.	Action like that of papaverine, but less potent. Has antitussive properties.
27	Nicotine $C_{10}H_{14}N_2$ [B ₂ ·H ₂ SO ₄]	Tobacco (leaf, stem) (Nicotiana spp.).	World-wide.	BP = 247; (a) _D = -169° in w.; n _D = 1.5282; [(a) _D = +88° in w.].	s.w., oils, most organic solvents; [s.w., al.].	Causes initial and transient stimulation, then depression, paralysis of autonomic ganglia; mild CNS stimulation; paralyzes skeletal muscle; absorbed from skin and mucous membrane; rapidly detoxi- fied. Insecticide.
28	Papaverine $C_{20}H_{21}NO_4$ [B·HCl]	Opium, also synthetic.		MP = 147; opt. inactive; [MP = 225].	s.al. 1:45, hot al. 1:4; sl.s.eth., bz., pet.eth.; i.w.; [s.al., chl., w. 1:40].	No narcotic action; paralyzes smooth muscle of intestines and blood vessels.
29	Pelletierine $C_8H_{15}NO$ [B ⁺ tannate]	Pomegranate (bark) (Punica granatum).	Subtropical lands.	BP = 195 (inert atmosphere); a mixture; [tannic acid salt of several Punica alkaloids].		Easily oxidized, becoming resinous in air. Acts on central and peripheral nervous system, voluntary muscle; selectively acts on optic nerve; effective against tapeworm.
30	Physostigmine (Eserine) $C_{15}H_{21}N_3O_2$ [B·C ₇ H ₆ O ₃ (salicylate)]	Calabar bean (Physostigma venenosum).	W. Africa, India, Brazil.	MP = 105; (a) _D = -76° in chl., -120° in bz.; [MP = 185-187].	s.al., bz., chl., oils; [s.w. 1:75, al. 1:16, chl. 1:6].	Inhibits cholinesterase, acts to stimulate skeletal muscle and as parasympathomimetic; causes pupillary constriction and spasm of accommodation; readily absorbed from GI tract and increases tone and motility; eliminated through kidney.
31	Pilocarpine $C_{11}H_{16}N_2O_2$ [B·HNO ₃]	Jaborandi (Pilocarpus spp.).	S. America.	MP = 34; (a) _D = +100° in chl.; [MP = 178; (a) _D = +83° in w.].	s.w., al., chl.; i.eth.; [s.w. 1:6.4].	Parasympathomimetic; stimulates involuntary smooth muscle, gland cells, sweat, salivary and gastric glands; causes pupillary con- striction; diaphoretic; depresses heart; partly destroyed in body; greater part excreted in urine.
32	Protoveratrine $C_{39}H_{61}O_{13}N$	Hellebore (root). (Veratrum viride)	N. America	MP = 283; (a) _D = -9 in chl.	s.al., chl.; i.w., bz.	Slows heart rate; lowers systemic blood pressure; side effects include nausea, diarrhea.
33	Quinidine $C_{20}H_{24}N_2O_2 \cdot 2H_2O$ a [B ₂ ·H ₂ SO ₄ ·2H ₂ O] b [B ₂ ·H ₂ SO ₄ ·4H ₂ O]	Cinchona spp. also by isomerization of quinine.	S. America, Java.	MP = 175; (a) _D = +230° in chl.; a [(a) _D = +212° in al.].	s.al. 1:36, chl. 1:16, eth. 1:56; sl. s.w.; a [s.w. 1:90]; b [s.w. 1:8].	Stereoisomer of quinine. Acts on heart to increase excitability, slow conduction and increased refractory period; can stop auricular fibril- lation; like quinine in other actions.
34	Quinine $C_{20}H_{24}N_2O_2$ (also + 3H ₂ O) a [B ₂ ·H ₂ SO ₄ ·2H ₂ O] b [B ₂ ·H ₂ SO ₄ ·7H ₂ O] c [B·HCl·2H ₂ O]	Cinchona spp (bark).	S. America, Java.	MP = 177; (a) _D = -169° in al., -117° in chl.	s.al. 1:1, chl. 1:1.2, bz. 1:80, eth. 1:250; a [s.al. 1:120, w. 1:810]; b [s.w. 1:9]; c [s.w. 1:16].	Lethal to asexual erythrocyte forms of malarial parasite; mildly stimulates uterus; antipyretic; local irritant; absorbed from GI tract; largely destroyed in body. Cardiac actions like that of quinidine but less pronounced.
35	Reserpine (Serpassil) $C_{33}H_{40}N_2O_9$	Rauwolfia serpentina.	India.	MP = 278; (a) _D = -118° in chl.	s.chl., bz., eth.ac.; sl.s. acet., me.al., eth., w.	Hypotensive, CNS sedative action.
36	Scopolamine (Hyoscyne) $C_{17}H_{21}NO_4$	Datura, Hyoscyamus, and Scopolia spp.	World-wide.	Liquid; (a) _D = -28° in w.; also cryst. + H ₂ O, MP = 54; [MP = 195 (anhydrous); (a) _D = -26° in w.].	s.al., eth., chl., w. 1:95; sl.s.bz., pet.eth.; [s.w. 1:1.5, al. 1:20].	Causes sedation, sleep, and amnesia; otherwise like atropine.
37	Sparteine $C_{15}H_{26}N_2$ [B·H ₂ SO ₄ ·5H ₂ O]	Lupinus and Spartium spp.	Europe.	Liquid; BP = 173 at 8 mm Hg; n _D = 1.5312; (a) _D = -16.4° in al.; [d. 136].	s.al., chl., eth., w. 1:325; [s.w. 1:1, al. 1:3].	Paralyzes autonomic ganglia; slows heart rate; curare-like action.
38	Strychnine $C_{21}H_{22}N_2O_2$ [B ₂ ·H ₂ SO ₄ ·5H ₂ O, also 6H ₂ O]	Strychnos spp (seed), especially Strychnos nux-vomica.	India, Indo-China.	MP = 268-90, varies with rate of heating; (a) _D = -139° in chl.	s.chl. 1:5, al. 1:150, bz. 1:180; i.w.; [s.w. 1:35, al. 1:81, glyc. 1:6].	Stimulates CNS; increases reflex excitability of spinal cord; sensi- tizes sensory cortex, medulla; readily absorbed from GI tract.
39	Thebaine $C_{19}H_{21}NO_3$	Opium.		MP = 193; (a) _D = -219° in al.	s. hot al. 1:15, chl. 1:13, bz. 1:25, pyr. 1:12.	Violent tetanic poison, no med. use per se. Source material for valuable narcotics.
40	Theobromine $C_7H_8N_4O_2$	Cacao bean (Theobroma cacao).	S. and Central America.	Sublimes 290; opt. inactive.	sl. s. w., al.; s. alkali.	Action like that of caffeine.
41	Theophylline $C_7H_8N_4O_2$ [B·Na acetate]	Tea (Thea sinensis), also synthetic.	China, India.	MP = 270-274; opt. inactive.	s.w. 1:120, al. 1:80, chl. 1:110, alkali; [s.w. 1:25].	Action like that of caffeine. [Contains 27% Na acetate]
42	Tubocurarine chloride $C_{38}H_{44}N_2O_6Cl_2 \cdot 5H_2O$	Curare (Chondroden- dron tomentosum).	S. America	d. 268; (a) _D = +190° in w.	s.w. 1:20, al.; i.chl., bz., pyr., acet.	Paralyzes skeletal muscles by blocking myoneural junction; blocks autonomic ganglia; not absorbed from GI tract.
43	Veratramine $C_{27}H_{39}NO_2$	Veratrum spp.	N. and S. America.	MP = 206; (a) _D = -71° in al.	s.al., me.al.	Inhibits cardioacceleration of epinephrine, sympathomimetic amines; CNS stimulant.
44	Yohimbine $C_{21}H_{26}N_2O_3$ [B·HCl]	Corynanthe yohimbe.	Africa	MP = 234; (a) _D = +108° in pyr.; [MP = 302; (a) _D = +103° in w.].	s.al., chl.; sl.s.eth., w.; [s.w. 1:120, al. 1:400].	Adrenolytic; causes antidiuresis; mild local anesthetic.

1/ In salt formula, B = base. 2/ Abbreviations: acet. = acetone; al. = alcohol (ethyl 95%); bz. = benzene; chl. = chloroform; d. = decomposes; dil. = dilute; eth. = ether; eth. ac. = ethyl acetate; glyc. = glycerol; i. = insoluble; me.al. = methyl alcohol; mod. = moderately; opt. = optically; pet. eth. = petroleum ether; pyr. = pyridine; s. = soluble; sl. = slightly; v. = very; w. = water. 3/ CNS = central nervous system; crys. = crystalline; GI = gastrointestinal; med. = medicinal.

361. TOXIC PRODUCTS: PLANTS

Part I: IRRITANTS

Plant	Type or Class	Compound	Irritant		Toxic Action or Effect
			Empirical Formula		
1 Anemone (<i>Anemone japonica</i>)	Oil	Protoanemonin	C ₅ H ₄ O ₂		Local irritation.
2 Baneberry (<i>Actaea</i> spp)					Acrid juice an emeto-purgative; cardiotoxic.
3 Chaulmoogra oil (<i>Hydnocarpus</i> spp)	Cyclic acid	Chaulmoogric acid	C ₁₈ H ₂₂ O ₂		Irritation of digestive tract, liver, kidneys.
4 Christmas rose (<i>Helleborus niger</i>)	Glycoside	Helleborein	C ₃₇ H ₅₆ O ₁₈		Intense irritation of mucous membranes.
5 Conringia (<i>Conringia orientalis</i>)	Volatile oil	Allyl isothiocyanate	C ₃ H ₅ CNS		Local irritation.
6 Crab's-eye vine (<i>Abrus precatorius</i>)	Toxalbumin	Abrin			Severe gastroenteritis.
7 Croton (<i>Croton tiglium</i>)		Croton resin			Severe local irritation.
8 Cyclamen (<i>Cyclamen europaeum</i>)	Glycosidal saponin	Cyclamin			Irritation of gastrointestinal tract.
9 Daphne (<i>Daphne mezereum</i>)	Glycoside	Daphnin	C ₁₅ H ₁₆ O ₉		Irritation of gastrointestinal tract; convulsions.
10 Indian turnip (<i>Arisaema triphyllum</i>)	Saponin				Irritation of mucous membranes; gastroenteritis.
11 Juniper (<i>Juniperus</i> spp)	Volatile oil				Inflammation of gastrointestinal tract.
12 Milkweed (<i>Calotropis</i> spp)	Milky juice				Violent local irritation; fatal gastroenteritis.
13 Mustard (<i>Brassica</i> spp)	Volatile oil	Allyl isothiocyanate	C ₃ H ₅ CNS		Local irritation.
14 Pine (<i>Pinus</i> spp)	Volatile oil	Oil of turpentine			Irritation of skin, kidneys.
15 Pyrethrum flowers (<i>Chrysanthemum cinerariaefolium</i> , 16 <i>C. coccineum</i> , or <i>C. marschallii</i>)		Pyrethrin I	C ₂₁ H ₃₀ O ₃		Irritation of eyes and mucous membranes.
		Pyrethrin II	C ₂₂ H ₃₀ O ₅		
		Cinerin I	C ₂₀ H ₂₈ O ₃		
		Cinerin II	C ₂₁ H ₂₈ O ₅		
19 Radish (<i>Raphanus raphanistrum</i>)	Volatile oil	Allyl isothiocyanate	C ₃ H ₅ CNS		Local irritation.
20 Skunk cabbage (<i>Symplocarpus foetidus</i>)					Severe irritation of mucous membranes; violent gastroenteritis may be fatal.
21 Snakeroot (<i>Aristolochia</i> spp)	Volatile oil	Borneol ester, pinene			Irritation of gastrointestinal tract, kidneys.
22	Alkaloid	Aristolochine	C ₁₇ H ₁₉ NO ₃		
23 Sneezeweed (<i>Helenium autumnale</i>)		Helenalin			Gastroenteritis, muscular paralysis.
24 Sneezeweed (<i>H. hoopesii</i>)	Glycoside	Dugaldin			Salivation, vomiting, diarrhea.
25 Snowberry (<i>Chiococca racemosa</i>)	Glycoside	Caincin	C ₄₀ H ₆₄ O ₁₈		Emeto-cathartic; severe gastroenteritis.
26 Soap-bark tree (<i>Quillaja saponaria</i>)	Sapogenin	Quillaic acid	C ₃₀ H ₄₆ O ₅		Severe local irritation.
27 Wood-fern (<i>Dryopteris</i> spp)		Aspidol	C ₁₂ H ₁₆ O ₄		Irritation of gastrointestinal tract.
28		Filicinic acid	C ₈ H ₁₀ O ₃		

Part II: REPELLENTS

Plant	Type or Class	Compound	Empirical Formula	Repellent	
				Insects Repelled	Toxicity to Higher Animals ¹
1 Camphor tree (<i>Cinnamomum camphora</i>)	Ketone	Camphor	C ₁₀ H ₁₆ O	Mosquitoes	Increased sensibility; convulsions.
2 Cinnamon tree (<i>Cinnamomum</i> spp)	Volatile oil	Oil of cinnamon		Mosquitoes	Inflammation of gastrointestinal tract.
3 Citronella grass (<i>Cymbopogon nardus</i>)	Oil	Citronella, geraniol		Mosquitoes	
4 Eucalyptus (<i>Eucalyptus</i> spp)	Oil	Eucalyptol	C ₁₀ H ₁₈ O		Inflammation of stomach; nausea; vomiting; dizziness; muscular weakness; fatal collapse.
5		Pinene	C ₁₀ H ₁₆	Cockroaches	
6		Eudesmol	C ₁₅ H ₂₆ O		
7 Horse-radish (<i>Radicula armoracia</i>)	Glycoside	Sinigrin	C ₁₀ H ₁₆ KNO ₉ S ₂	Cockroaches	Corrosive; inflammation, vesication of skin.
8 Juniper (<i>Juniperus communis</i>)	Oil	Camphene	C ₁₀ H ₁₆		Local irritation; may injure kidneys.
9		α-Pinene	C ₁₀ H ₁₆		
10		Terpineol	C ₁₀ H ₁₈ O	Cockroaches	
11		Cadinene	C ₁₅ H ₂₄		
12 Sassafras (<i>Sassafras albidum</i>)	Oil	Camphor	C ₁₀ H ₁₆ O		Paralysis of respiratory center; fatty degeneration of heart, liver, kidneys.
13		Safrol	C ₁₀ H ₁₀ O ₂	Screw-worm flies	
14		Eugenol	C ₁₀ H ₁₂ O ₂		
15 Thyme (<i>Thymus vulgaris</i>)	Volatile oil	Cymene, pinene, thymol		Mosquitoes	Excitement.
16 Wormseed (<i>Chenopodium ambrosioides anthelminticum</i>)	Volatile oil	Ascaridole	C ₁₀ H ₁₆ O ₂		Temporary deafness; convulsions; gastric irritation; nephritis.
17		Cymene	C ₁₀ H ₁₄	Mosquitoes	

/1/ When ingested or applied locally in high concentrations.

Part III: MISCELLANEOUS

Plant	Type or Class	Compound	Toxic Component		Toxic Action or Effect
			Empirical Formula		
1 Anamirta (<i>Anamirta cocculus</i>)	Neutral principle	Picrotoxin	C ₃₀ H ₃₄ O ₁₃		Convulsions; paralysis; death by asphyxia.
2 Andromeda (<i>Andromeda</i> spp)	Neutral principle	Andromedotoxin	C ₃₁ H ₅₀ O ₁₀		Vomiting; paralysis of motor nerve endings; cardiotoxic.
3 Aster (<i>Aster xylorrhiza</i>)	Resinous				Impaired vision; depraved appetite; abdominal pain.
4 Beet (<i>Beta vulgaris</i>), leaf only	Inorganic	Oxalic acid, nitrates	C ₂ H ₂ O ₄		Inability to stand; muscular tremors, tetany.
5 Buckwheat (<i>Fagopyrum esculentum</i>)	Photodynamic	Porphyry			Photosensitization.
6 Carissa (<i>Carissa ovata</i>)	Glycoside	Carissin	C ₃₂ H ₅₀ O ₁₂		Heart derangement.
7 Cocklebur (<i>Xanthium</i> spp)	Glycoside	Xanthostrumarin			Depression; nausea; vomiting; labored respiration.
8 Coriaria (<i>Coriaria myrtifolia</i>)	Glycoside	Coriamyrtin	C ₁₅ H ₁₈ O ₅		Convulsions; paralysis; death by asphyxia.
9 Cotton (<i>Gossypium hirsutum</i>), seed only		Gossypol	C ₃₀ H ₃₀ O ₅		Edema of lungs; irritation of kidneys, gastrointestinal tract.
10 Dogbane (<i>Acokanthera venenata</i>)	Glycoside	Abyssin (ouabain)	C ₃₂ H ₅₀ O ₁₂		Inflammation, gastrointestinal tract; cardiotoxic.
11 Flax (<i>Linum usitatissimum</i>)	Glycoside	Phaseolunatin	C ₁₀ H ₁₇ O ₆ N		Asphyxia.
12 Hyena poison (<i>Hyaenanche capensis</i>)		Hyaenanchin	C ₁₅ H ₁₈ O ₇		Convulsions; paralysis; death by asphyxia.
13 Laurel (<i>Kalmia</i> spp)		Andromedotoxin	C ₃₁ H ₅₀ O ₁₀		See Andromeda, Line 2.
14 Lippia (<i>Lippia rehmanni</i>)	Photodynamic	Icterogenin	C ₃₄ H ₅₂ O ₆		Photosensitization.
15 Marsdenia (<i>Marsdenia cundurango</i>)	Glycoside	Condurangin	C ₃₅ H ₅₄ O(CH ₃) ₂		Convulsions followed by paralysis.
16 Oleander (<i>Nerium oleander</i>)	Glycoside	Oleandrin	C ₃₁ H ₄₈ O ₉		Digitalis-like action.
17 Rhubarb (<i>Rheum</i> spp), leaf only	Inorganic	Oxalic acid	C ₂ H ₂ O ₄		Weakness; muscular tremors; tetany.
18 Sorghum (<i>Sorghum halepense</i>)	Cyanogenetic glycoside	Dhurrin	C ₁₄ H ₁₇ O ₇ N · H ₂ O		Asphyxia.
19 Strophanthus (<i>Strophanthus</i> spp)	Glycoside	Ouabain	C ₂₉ H ₄₄ O ₁₂ · H ₂ O		Digitalis-like action.
20 Sweetclover (<i>Melilotus</i> spp), spoiled	Anticoagulant	Dicoumarin	C ₁₉ H ₁₂ O ₆		Hemorrhages; retards blood coagulation.
21 Veronica (<i>Veronica nigritiana</i>)	Glycoside	Vernonin	C ₁₀ H ₂₄ O ₇		Digitalis-like action.
22 Water hemlock (<i>Cicuta</i> spp)	Neutral principle	Cicutoxin	C ₁₉ H ₂₆ O ₃		Violent convulsions.
23 Wild cherry (<i>Prunus</i> spp)	Cyanogenetic glycoside	Prunasin			Asphyxia.

362. TOLERANCES TO EXTREMES OF HEAT AND COLD: ANIMALS

The following abbreviations for sites of temperature measurement are used in this table: A = air; B = body; C = cloaca; G = gullet; I = intestine; R = rectum; S = stomach; T = throat; U = underground; W = water.

Part I: MAMMALS

Part I. MAMMALS							
Mammal		Specification	Site	Temperature °C (°F)	Duration	Humidity %	Survival n/n ¹
1	Man (<i>Homo sapiens</i>)	Adult	R	25-29(77-84.2)	1 hr	36-84 ⁴ 11-21 ⁵	0/7 ²
2			W	15(59)	50-70 min		6/6 ³
3			A	29-36(84.2-96.8)			
4			A	43-48(109.4-118.4)			
5	Anteater, spiny (<i>Tachyglossus aculeatus</i>)	2.36 kg	I ⁶	26-29(78.8-84.2) ⁷	77-102 min		3/3
6		1.67 kg	I ⁶	40(104) ⁸	70 min		0/1
7	Armadillo (<i>Dasypus novemcinctus</i>)	Adult	I ⁶	29-33(84.2-91.4) ⁹	3-6 hr		6/6
8	Bat (<i>Myotis lucifugus</i>)	5.2 g	A	0.5(32.9) ¹⁰	2 hr		5/5
9		6.4 g	A	44(111.2) ¹¹	30 min		0/5
10	Cat (<i>Felis catus</i>)	Adult	I ⁶	43(109.4) ¹²	Few min	Dry air 35-65 ¹³	50%
11			A	41-43(105.8-109.4) ¹³	7 hr		100%
12	Cattle (<i>Bos indicus</i> , <i>B. taurus</i>)	Adult	A	-13(8.6) ¹⁴	2 wk	66	6/6
13			A	41(105.8) ¹⁴	24 hr	51	3/3
14	Dog (<i>Canis familiaris</i>)	Adult	I ⁶	17(62.6) ¹⁵	65-118 min	Dry air	0/6
15		Adult	I ⁶	22-26(71.6-78.8) ¹⁶	15 min-26 hr		3/11
16		Adult	I ⁶	42(107.6) ¹²	Few min		50%
17		27.6 kg	W	0(32) ¹⁷	1-5 hr		4/4
18	Guinea pig (<i>Cavia porcellus</i>)	Adult	I ⁶	41-42(105.8-107.6) ¹⁸	7 hr		2/2
19			A	48(118.4)	100 ± 4 min	15	0/11
20	Hamster, golden (<i>Mesocricetus auratus</i>)	Adult	I ⁶	2-4(35.6-39.2) ¹⁹			8/20
21			A	4-6(39.2-42.8)	6 da		22/45
22	Mouse (<i>Mus musculus</i>)	45-109 g	I ⁶	9-15(48.2-59) ²⁰	25-65 min		20/20
23		Adult	A	38(100.4) ¹²	3 hr		50%
24	Rabbit (<i>Oryctolagus cuniculus</i>)	Adult	I ⁶	19-25(66.2-77) ²¹	30 min	95 ²⁵ 35 ²⁵	87/103
25		1.76 kg	A	-35(-31) ²²	3½-6½ hr		0/9
26		Adult	W	3.5 av (38.3) ²³	21 min (av)		16/24
27		3.95 kg	W	10(50) ²⁴	30 min		4/4
28		Adult	A	35(95) ²⁵	7 hr		2/2
29		Adult	A	38(100.4) ²⁵	7 hr		2/2
30	Rat (<i>Rattus rattus</i>)	235 g	A	-35(-31) ²²	45-120 min	15	0/12
31		237 g	W	10(50) ²⁴	10 min		3/3
32		Adult	A	40(104) ²⁶	213 ± 36 min		0/16
33		Adult	A	49-51(120.2-123.8) ²⁶	31 ± 1 min		0/36
34	Sheep (<i>Ovis aries</i>)	Adult	I ⁶	42(107.6) ²⁷	7 hr		100%
35			A	43(109.4) ^{27, 28}	7 hr	65	100%
36	Sloth (<i>Bradypus griseus</i> and/or	Adult	I ⁶	24(75.2) ²⁹			1/2
37	<i>Choloepus hoffmani</i>)		I ⁶	40 ± (104±) ³⁰			
38	Squirrel (<i>Citellus pygmaeus</i>)	120-265 g	B	2-6(35.6-42.8) ³¹			11/19
39	Swine, Berkshire (<i>Sus scrofa</i>)	59 kg	I	42(107.6) ²⁷			100%
40			A	38-41(100.4-105.8) ³²			

/1/ n = number survived; n¹ = number in test. Percentages are per cent survived. /2/ WW II concentration camp; subjects cooled rapidly in water. /3/ Subjects refused to continue, or investigator considered continuance detrimental. /4/ Range at onset of heat exhaustion in humid climates. /5/ Range at onset of heat exhaustion in desert climates. /6/ May include rectum and colon. /7/ In metabolic chamber placed in water bath at 4-8°C (39.2-46.4°F). /8/ In metabolic chamber placed in water bath at 35-37°C (95-98.6°F). /9/ In cold room at 0-21°C (32-69.8°F). /10/ In metabolic chamber; -5°C (23°F) fatal to hibernating bats. /11/ In metabolic chamber at high humidity. /12/ Temperature for 50% mortality estimated from curve. /13/ Upper limits of temperature and humidity cats can withstand for 7 hr. /14/ Indoors; air flow 22.9 cm/sec. /15/ In ice water at 1.5-6°C (34.7-42.8°F); dogs etherized during initial cooling stages. /16/ Anesthetized and cooled with ice for 1¼ to 27 hr. /17/ Serious impairment in 3 dogs in 1 hr; 4th not markedly affected. /18/ 7 hr exposure to environmental temperature of 41°C (105.8°F). /19/ In cold water at 3°C (37.4°F), or in cold air. /20/ In cold air, about -10°C (14°F). /21/ Immersed in cold water, then exposed to cold air (total ½ hr). /22/ In controlled temperature room, air flow 89.4 cm/sec. /23/ Body temperature in all but three fell below 19°C (66.2°F). /24/ Serious impairment, approaching unconsciousness. /25/ Upper limits tolerated for 7 hr in controlled temperature room. /26/ In heated room. /27/ In controlled temperature room; near heat tolerance limit. /28/ Merino wethers sheep. /29/ In cold room, 10-16°C (50-60.8°F); rectal temperature of 23-25°C (73.4-77°F) for 7 hr for animal that died and for 9 hr for survivor. /30/ Outdoor exposure at 35-40°C (95-104°F) in sunlight; several died. /31/ In refrigerator 2-4 hr at -13 to -19°C (8.6 to -2.2°F); all but one of eight that died had body temperature of 0°C (32°F) or less. /32/ In controlled temperature room; withstood 38°C (100.4°F) at 65 relative humidity, but could not tolerate 41°C (105.8°F) at any humidity.

Part II: BIRDS

Bird	Specification	Body Temperature		Ambient Temperature		Survival n/n ¹
		Site	°C (°F)	Site	°C (°F)	
1 Canary (<i>Serinus serinus canaria</i>)	20 g			A	-35 (-31)	0/6
2 Duck (<i>Anas platyrhynchos</i>)	1.45-1.8 kg			A	-40 (-40)	168-264
3 var. domesticus	2 kg			A	-40 (-40)	384
4 wild mallard	1 kg			A	-18 (-0.4)	225
5	♂	C	19.4-22.2 (68.9-72)	W	6-10 (42.8-50)	1.1-1.5
6	♀	C	22.8-23.6 (73-74.5)	W	9-11.7 (48.2-53.1)	1.1-1.5
7	♀	C	27.8-29.4 (82-84.9)	W	20-27.8 (68-82)	35-44
8	♀	C	27.8-31.1 (82-88)	W	20-27.8 (68-82)	23-37
9	1.6 kg	C	21-41 (69.8-105.8)	A	-35(-31)	3.3-16
10 Fowl (<i>Gallus gallus</i>) var. domesticus	1.5 kg	C	21-41 (69.8-105.8)	A	-35(-31)	16-29.5
11 Embryo (0 da)				A	-5(23)	48
12 Embryo (5 da)				A	0(32)	38
13 Embryo (17 da)				A	10(50)	144
14 Embryo (0-5 da)				A	21(69.8)	120
15 Embryo (0-21 da)				A	28(82.4)	504
16 Embryo (0-21 da)				A	43(109.4)	504
17 Junco, slate-colored (<i>Junco hyemalis</i>)	21.8 g			A	-14(6.8)	37
18	20.7 g			A	37(98.6)	12
19 Pheasant, ring-neck (<i>Phasianus colchicus</i>)	1.05 kg			A	-9 (15.8)	336
20	1.15 kg			A	-1 ± (30.2±)	340
21		R	46(114.8)			<1
22 Pigeon (<i>Columba livia</i>)	300-400 g			A	-40(-40)	0.3-0.5
23	300-400 g			A ³	-40(-40)	24

/1/ n = number survived; n¹ = number in test. Percentages are per cent survived. /2/ Plucked birds. /3/ In path of 5 mph breeze.

362. TOLERANCES TO EXTREMES OF HEAT AND COLD: ANIMALS (Continued)

The following abbreviations for sites of temperature measurement are used in this table: A = air; B = body; C = cloaca; G = gullet; I = intestine; R = rectum; S = stomach; T = throat; U = underground; W = water.

Part II: BIRDS (Concluded)

	Bird	Specification	Body Temperature		Ambient Temperature		Survival n/n ¹
			Site	°C (°F)	Site	°C (°F)	
24	Pigeon (<i>Columba livia</i>)	300-400 g			A ³	-40(-40)	48
25	(concluded)	300-400 g			A	-40(-40)	96-120
26		300-400 g			A	-40(-40)	144
27	Quail, bob white (<i>Colinus virginianus</i>)	165 g			A	-18 (0.4)	60
28	Grouse, ruffed (<i>Bonasa umbellus</i>)	615 g			A	-18(-0.4)	185
29	Sparrow, house (<i>Passer domesticus</i>)	29 ± g			A	-39 to -30(-38.2 to -22)	3.7-5.3
30					A	-29 to -20(-20.2 to -4)	3.2-4.4
31					A	-19 to -10(-2.2 to 14)	11.3-21.4
32					A	38-39(100.4-102.2)	9.9-13.6
33					A	41-45(105.8-113)	0.5-1
34	Sparrow, tree (<i>Spizella arborea</i>)	21.1 g			A	-13(8.6)	31
35	Sparrow, white-crowned (<i>Zonotrichia leucophrys</i>)	20.5 g			A	38(100.4)	7
36		37.5 g			A	-18(0.4)	19
37		32.4 g			A	38(100.4)	5
38	Sparrow, white-throated (<i>Zonotrichia albicollis</i>)	26.6 g			A	-17(1.4)	16
39		27.8 g			A	-37(98.6)	7
40	Turkey, wild (<i>Meleagris gallopao</i>)	4.9 kg			A	-18(0.4)	324
41	Wren, house (<i>Troglodytes aedon</i>)				A	-13.9(7)	4
42			T	6.8-11.3(44.2-52.3)	A	6.4-10.1(43.5-50.2)	<1
43			T	21.7(71.1)	A ⁴	10 ± 1(50±)	<1
44			T	23.7(74.7)	A ⁴	10 ± (50±)	<1
45			T	45.3(113.5)	A ⁵	37.9±(100.2)	<1
46			T	46.6(115.9)	A	45.2(113.2)	<1.5
47			T	46.8(116.2)	A ⁵	37.9 ± (100.2)	<1

/1/ n = number survived; n¹ = number in test. Percentages are per cent survived. /3/ In path of 5 mph breeze. /4/ Low and falling air temps.

/5/ High and rising air temps.

Part III: REPTILES

Values are LD₅₀ temperature tolerance limits, i.e., temperatures survived by 50% of test animals. Counts were made after animals regained "normal" temperature and behavior. Information on site of measurement, if available, is given in brackets.

	Reptile	Lower Limit		Reptile	Lower Limit	
		°C (°F)	Upper Limit °C (°F)		°C (°F)	Upper Limit °C (°F)
1	Alligator (<i>Alligator mississippiensis</i>)	4(39.2)[C]	39(102.2)[C]	13	Snake, garter (<i>Thamnophis radix</i>)	-2(28.4)[U]
2	Lizard, chuckwalla (<i>Sauromalus obesus</i>)		44(111.2)[C]	14	Snake, garter (<i>T. radix</i>)	0(32)[A]
3	Lizard, collared (<i>Crotaphytus collaris</i>)		46(114.8)[C]	15	Snake, glossy (<i>Arizona elegans</i>)	41(105.8)[A]
4	Lizard, crested (<i>Dipsosaurus dorsalis</i>)		47.5(117.5)[C]	16	Snake, leaf-nosed (<i>Phyllorhynchus decurtatus</i>)	42(107.6)[C]
5	Lizard, European (<i>Lacerta agilis</i>)	-4(24.8)	44(111.2)[B]	17	Snake, shovelnose (<i>Sonora occipitalis</i>)	38(100.4)[C]
6	Lizard, fringe-footed (<i>Uma notata</i>)		45(113)[C]	18	Snake, sidewinder (<i>Crotalus cerastes</i>)	37(98.6)[C]
7	Lizard, ground (<i>Uta stansburiana</i>)		48(118.4)[C]	19	Snake, water (<i>Natrix sipedon</i>)	41(105.8)[C]
8	Lizard, horned (<i>Phrynosoma platyrhinos</i>)		46(114.8)[C]	20	Turtle, central painted (<i>Chrysemys bellii marginata</i>)	43(109.4)[A]
9	Lizard, night (<i>Xantusia vigilis</i>)		38(100.4)[C]	21	Turtle, land (<i>Testudo norsefieldi</i>)	40(104)[C]
10	Lizard, slowworm (<i>Anguis fragilis</i>)		37(98.6)[A]	22	Turtle, painted (<i>Pseudemys elegans</i>)	1(33.8)[C]
11	Lizard, swift (<i>Sceloporus graciosus</i>)		43.6(110.5)[C]	23	Turtle, snapping (<i>Chelydra serpentina</i>)	46(114.8)[C]
12	Lizard, whiptail (<i>Cnemidophorus tessellatus</i>)		46(114.8)[C]			40(104)[C]

Part IV: AMPHIBIANS

Values are LD₅₀ temperature tolerance limits, i.e., temperatures survived by 50% of test animals. Counts were made after animals regained "normal" temperature and behavior. Information on site of measurement, if available, is given in brackets.

	Amphibian	Lower Limit		Amphibian	Lower Limit	
		°C (°F)	Upper Limit °C (°F)		°C (°F)	Upper Limit °C (°F)
1	Bullfrog (<i>Rana catesbeiana</i>), embryo	15(59)[W]	32(89.6)[W]	10	Frog, water (<i>Rana esculenta</i>)	-0.5(31.1)[C]
2	Bullfrog (<i>R. catesbeiana</i>), large tadpoles ¹		36(96.8)[W]	11	Frog, wood (<i>R. sylvatica</i>), embryo	2.5(36.5)[W]
3	Frog, green (<i>R. clamitans</i>)	-0.5(31.1)[S]	22(71.6)[A] ²	12	Frog, European wood (<i>R. temporaria</i>), embryo	1.4(29.5)[G]
4	Frog, green (<i>R. clamitans</i>), embryo	12(53.6)[W]		13	Salamander, European spotted (<i>Salamandra maculosa</i>)	32.5(90.5)[W] ⁵
5	Frog, leopard (<i>R. pipiens</i>), embryo ³	11(51.8)[W]	34(93.2)[W]	14	Toad, American (<i>Bufo americanus</i>), embryo	-3(26.6)[W]
6	Frog, leopard (<i>R. pipiens</i>), embryo ⁴	5(41)[W]	28(82.4)[W]	15	Toad, clawed (<i>Xenopus laevis</i>)	11(51.8)[W]
7	Frog, pickerel (<i>R. palustris</i>), embryo	7(44.6)[W]	30(86)[W]	16	Toad, common (<i>Bufo bufo</i>)	31(87.8)[W]
8	Frog, spring peeper (<i>Hyla crucifer</i>), embryo	<6(42.8)[W]	28(82.4)[W]	17	Toad, fire-bellied (<i>Bombinator igneus</i>)	0(32)[C]
9	Frog, tree (<i>H. arborea</i>)	-0.5(31.1)[C]				33(91.4)[C]

/1/ Tadpoles of known ages, for brief exposures. /2/ 12 hr exposure. /3/ From Florida. /4/ From Vermont. /5/ 1 hr exposure.

Part V: FISHES

Values are LD₅₀ temperature tolerance limits, i.e., water temperatures survived by 50% of test animals. Counts were made by observing or estimating the number killed during exposure, or within a reasonable time thereafter in which it could be safely assumed that all deaths were attributable to the temperature effects. Exposure periods, in hours, are given in brackets.

	Fish	Acclimated to °C (°F)	Lower Limit		Fish	Acclimated to °C (°F)	Lower Limit	
			°C (°F) [hr]	Upper Limit °C (°F) [hr]			°C (°F) [hr]	Upper Limit °C (°F) [hr]
1	Bass, large mouth (<i>Micropterus salmoides floridanus</i>) ¹	20(68)	5(41)[24]	32(89.6)[72]	13	Dace, blacknose (<i>Rhinichthys a. atratulus</i> , <i>R. a. mealegrus</i>) ¹	5(41)	27(80.6)[340]
2	Bluegill (<i>Lepomis macrochirus macrochirus</i>) ¹	30(86)	11(51.8)[24]	34(93.2)[72]	14	Eelpout (<i>Zoarces anguillaris</i>) ³	25(77)	29(84.2) ² [340]
3	Bluegill (<i>L. macrochirus purpureus</i>) ¹	10(50)		28(82.4)[24]	15	Flounder, winter (<i>Pseudopleuronectes americanus</i>) ³	-2(28.4)	28(82.4) ²
4	Bluegill (<i>L. macrochirus purpureus</i>) ¹	30(86)	3(37.4)[24]	31(87.8)[>60]	16	Goldfish (<i>Carassius auratus</i>) ¹	2(35.6)	28(82.4)[14]
5	Bullhead (<i>Ameiurus n. nebulosus</i> , <i>A. n. marmoratus</i>) ¹	20(68)	1(33.8)[24]	32(89.6)[96]	17	Greenfish (<i>Girella nigricans</i>) ³	17(62.6)	34(93.2)[14]
6	Catfish, channel (<i>Ictalurus lacustris lacustris</i> , <i>I. l. punctatus</i>) ¹	30(86)	7(44.6)[24]	35(95)[96]	18	Killifish (<i>Fundulus heteroclitus</i>) ³	24(75.2)	36(96.8)[14]
7	Chub, creek (<i>Semotilus a. atromaculatus</i>) ¹	15(59)	0(32)[24]	30(86)[>24]	19		37(98.6)	42(107.6)[14]
8		25(77)	6(42.8)[24]	34(93.2)[>24]	20		12(53.6)	5(41)[120]
9					21		18(64.4)	13(55.4)[72]
10					22		14(57.2)	1(33.8)[48]
11					23		20(68)	2(35.6)[48]
12					24			34(93.2)

/1/ Fresh-water fish. /2/ Upper limit in gradually rising temperatures. /3/ Marine fish. /4/ Approximate average survival time.

362. TOLERANCES TO EXTREMES OF HEAT AND COLD: ANIMALS (Continued)

The following abbreviations for sites of temperature measurement are used in this table: A = air; B = body; C = cloaca; G = gullet; I = intestine; R = rectum; S = stomach; T = throat; U = underground; W = water.

Part V: FISHES (Concluded)

Values are LD₅₀ temperature tolerance limits, i.e., water temperatures survived by 50% of test animals. Counts were made by observing or estimating the number killed during exposure, or within a reasonable time thereafter in which it could be safely assumed that all deaths were attributable to the temperature effects. Exposure periods, in hours, are given in brackets.

Fish	Acclimated to °C (°F)	Lower Limit °C (°F) [hr]	Upper Limit °C (°F) [hr]	Fish	Acclimated to °C (°F)	Lower Limit °C (°F) [hr]	Upper Limit °C (°F) [hr]
25 Minnow, fathead	20(68)	2(35.6)[24]	32(89.6)[133]	44 Shiner, common	5(41)		27(80.6)[133]
26 (Pimephales promelas) ³	30(86)	11(51.8)[24]	33(91.4)[133]	45 (Notropis cornutus	25(77)	4(39.2)[24]	31(87.8)[133]
27 Minnow, blunt-nose	15(59)	1(33.8)[24]	31(87.8)[133]	46 frontalis) ¹	30(86)	8(46.4)[24]	31(87.8)[133]
28 (Hyborhynchus notatus) ¹	25(77)	8(46.4)[24]	33(91.4)[133]	47 Shiner, common (N.	25(77) ⁵		32(89.6)[133] ⁵
29 Mosquito fish (Grambusia	15(59)	2(35.6)[24]	35(95)[>66]	48 cornutus chrysocephalus) ¹	30(86) ⁶		34(93.2)[133] ⁶
30 affinis affinis, G.a.holbroki)	35(95)	15(59)[24]	37(98.6)[>66]	49 Shiner, lake	5(41)		23(73.4)[133]
31 Perch (Perca flavescens) ¹	5(41)		21(69.8)[96]	50 (N. atherinoides) ¹	15(59)	2(35.6)[24]	29(84.2)[133]
32 Winter	25(77)	4(39.2)[24]	30(86)[>96]	51	25(77)	8(46.4)[24]	31(87.8)[133]
33 Summer	25(77)	9(48.2)[24]	32(89.6)[>96]	52 Shiner, golden	20(68)	8(46.4)[24]	32(89.6)[>66]
34 Salmon, spring (On-	5(41)		21.5(70.7)[168]	53 (Notemigonus c. cryso-	30(86)	11(51.8)[24]	35(95)[>66]
35 corhynchus tschawyscha)	20(68)	4.5(40.1)[92]	25.1(77.2)[168]	54 Sucker, common (Catosto-	15(59)		29(84.2)[133]
36 Salmon, sockeye	5(41)	0(32)[92]	22.2(72)[168]	55 mus commersoni) ¹	25(77)	5(41)[24]	29(84.2)[133]
37 (O. nerka)	20(68)	4.7(40.9)[92]	24.8(76.6)[168]	56 Sunfish	10(50)		28(82.4)[24]
38 Salmon, chum	5(41)		21.8(71.2)[168]	57 (Lepomis gibbosus) ¹	30(86)		24(75.2)[24]
39 (O. keta)	20(68)	6.5(43.7)[92]	23.7(74.7)[168]	58 Trout, brook	3(37.4)		23(73.4)[133]
40 Salmon, coho	5(41)	0.2(32.4)[92]	22.9(73.2)[168]	59 (Salvelinus fontinalis) ¹	20(68)		25(77)[133]
41 (O. kisutch)	20(68)	4.5(40.1)[92]	25(77)[168]	60	25(77)		25(77)[133]
42 Shad, gizzard (Dorosoma	25(77)	11(51.8)[24]	34(93.2)[48]				
43 cepedianum) ¹	35(95)	20(68)[24]	37(98.6)[48]				

/1/ Fresh water fish. /3/ Marine fish. /5/ Summer. /6/ Winter.

Part VI: INSECTS

Exposure periods, in hours, are given in brackets.

Insect		Speci- fica- tions	Activity Range °C (°F)	Biological Zero ¹ °C (°F)	Heat Death		Cold Death Temperature °C (°F) [hr]	
					°C (°F) [hr]	R.H. % ²		
Anoplura								
1	Louse, human (<i>Pediculus humanus</i>)	Adult	20-39(68-102.2) ³		50-55(122-131)[0.25-0.42]			
2		Adult			46-47(114.8-116.6)[1]			0-90
3		Adult			33-38(91.4-100.4)[24]			0-90
Coleoptera								
4	Beetle, diving (<i>Dysticus marginalis</i>)	Egg	10-27(50-80.6)	0(32)	31(87.8)			
5		Larva		1.38(34.5) ⁴				
6	Beetle, furniture (<i>Anobium striatum</i>)	Adult			42-46(107.6-114.8) [0.01-0.02]			
7	Beetle, Mexican bean (<i>Epilachna varivestis</i>)	Larva; adult			42.5(108.5)[3]	1-100		
8	Beetle, western pine (<i>Dendroctonus brevicornis</i>)	Larva	12.8-32(55-89.6)	4-7(39.2-44.6) ⁵	37.8-40.6(100-105.1)[0.5]		5-10(41-50)	
9	Mealworm, yellow (<i>Tenebrio molitor</i>)	Larva	12-20(53.6-68) ⁶		42-43(107.6-109.4)[1-3]	0-90		
10		Larva			38.5(101.3)[24]	0-90		
11	Tree borer, flat-headed apple- (<i>Chrysobothris femorata</i>)	Larva			53(127.4)[2]	10-15;95-100		
12	Weevil, bean (<i>Acanthoscelides obtectus</i>)	Egg			52(125.6)[0.17]		-8(17.6)	
13		Larva			-2(28.4)		-8(17.6)	
14		Pupa			-2(28.4)		-9(15.8)	
15		Adult		-2(28.4)	55(131)[0.06]		-8(17.6)	
16	Weevil, boll (<i>Anthonomus grandis</i>)	Adult	13.3-35(55.9-95)	3 to -4(37.4-24.8) ^{7,8}	50-60(122-140)			
17	Weevil, granary (<i>Sitophilus granarius</i>)	Adult	25(77) ⁶	9.5(49.1) ^{9,10}	49(120.2)[3]	20-60	-4 to -1(24.8-30.2) [1104]	
Diptera								
18	Cheese skipper (<i>Piophilidae casei</i>)	Larva			46-48(114.8-118.4) ¹¹ [24]	0-100		
19	Fly, green bottle (<i>Phaenicia sericata</i>)	Egg	10-30(50-86)	5-6(41-42.8)				
20		Larva	10-30(50-86)	4.2-10(39.6-50) ¹²				
21		Adult	20-38(68-100.4)	6.7-7.2(44.1-45) ⁵				
22	Fly, house (<i>Musca domestica</i>)	Egg	44-48(111.2-118.4) ¹³	5(41)	42.8-43(109-109.4)			
23		Larva		49(120.2)				
24		Pupa		>7.8(>46)	10(50)			
25		Adult	>15.6(>60.1) ⁶	6.7-7.2(44.1-45) ⁵	44.6(112.3)		0-1(32-33.8)[168] 0(32)[72]	
26	Fly, tsetse (<i>Glossina morsitans</i>)	Adult			44-46(11.2-114.8)[0.08]		-12(10.4)[0.2]	
27	Mosquito, malarial (<i>Anopheles quadrimaculatus</i>)	Larva			42(107.6)[0.12-0.3]			
28		Pupa			42(107.6)[0.08]			
29	Mosquito, northern house (<i>Culex pipiens</i>)	Egg					5	
30		Adult						44.5-45.6(112.1-114.1)	-17(1.4)
Hemiptera								
31	Aphid, potato (<i>Macrosiphum solanifolii</i>)	Adult			38.5(101.3)[1]	60		
32	Bedbug (<i>Cimex lectularis</i>)	Adult	12-22(53.6-71.6) ¹⁴	7.5(45.5) ⁵	34-43.5(93.2-110.3) ¹⁵ [1-24]	0-90		
33		Adult						
34	Greenbug (<i>Toxoptera graminum</i>)	Adult		1.7-4.5(35.1-40.1) ¹⁴	37.5-40(99.5-104.2)		-8.3(46.9)	
Heteroptera								
35	Bug, assassin (<i>Rhodnius prolixus</i>)	Nymph			40-43(104-109.4) ¹⁵ [1-24]	0-90		

/1/ Temperature at which all vital processes are arrested by cold. /2/ R.H. = relative humidity. /3/ Temp "preferred" by insect is 24-32°C (75.2-89.6°F). /4/ Cold stupor at 6°C (42.8°F). /5/ Cold stupor. /6/ Temp "preferred" by organism. /7/ Cold stupor at 13.3°C (55.9°F). /8/ Heat stupor at 35-50°C (95-122°F). /9/ Cold stupor at 13-15°C (55.4-59°F). /10/ Heat stupor at 28°C (82.4°F). /11/ The higher temp corresponds to a relative humidity of 60%. /12/ Cold stupor at 2°C (35.6°F). /13/ Temp "preferred" by larva is 30-37°C (86-98.6°F). /14/ Temp "preferred" by adult; relative humidity 24-44%. /15/ The higher temperature kills in 1 hr, the lower in 24 hr.

362. TOLERANCES TO EXTREMES OF HEAT AND COLD: ANIMALS (Concluded)

The following abbreviations for sites of temperature measurement are used in this table: A = air; B = body; C = cloaca; G = gullet; I = intestine; R = rectum; S = stomach; T = throat; U = underground; W = water.

Part VI: INSECTS (Concluded)

Exposure periods, in hours, are given in brackets.

Insect		Speci- fica- tions	Activity Range °C (°F)	Biological Zero ¹ °C (°F)	Heat Death		Cold Death Temperature °C (°F) [hr]
					°C (°F) [hr]	R.H. % ²	
Hymenoptera							
36	Bee, honey (<i>Apis mellifera</i>)	Adult	10-35(50-95)		46-48(114.8-118.4)[0.5]		-2 to -1(28.4-30.2)
Lepidoptera							
37	Borer, European corn- (<i>Pyrausta nubilalis</i>)	Larva			58(136.4)[0.18]		-31.7(-25.1)[0.17]
38	Moth, codling (<i>Carpocapsa pomonella</i>)	Egg		6.7-9.4(44.1-48.9)			
39		Larva		6.1-8.8(43-47.8)			
Orthoptera							
40	Cockroach, American (<i>Periplaneta americana</i>)	Adult			42-45(107.6-113)[1]	0-90	
41					37-49(98.6-120.2)[24]	0-90	
42	Cockroach, German (<i>Blattella germanica</i>)	Adult			43-45(109.4-113)[1]	0-90	
42							
Siphonaptera							
43	Flea, oriental rat (<i>Xenopsylla cheopis</i>)	Larva			40(104)[1]	0-90	
44		Adult			38-40.7(100.4-105.3) ¹⁵ [1-24]	0-90	

/1/ Temperature at which all vital processes are arrested by cold. /2/ R.H. = relative humidity. /15/ The higher temperature kills in 1 hr, the lower in 24 hr.

363. OPTIMAL TEMPERATURES AND HUMIDITIES FOR PHYSIOLOGICAL FUNCTIONS: ARTHROPODS

Several ranges represent extremes reported by different investigators.

Arthropod				Arthropod			
Temper- ature °C				Temper- ature °C			
Optimal Humidity %				Optimal Humidity %			
Function				Function			
Isopoda				Collembola			
1 Armadillium vulgare, adult	14-35	100	Survival	44 Dicyrtomia minuta, adult	25	100	Survival
2 Ligia occidentalis, adult	20-35	100	Survival	45 Entomobrya multifasciata, adult	25	100	Survival
3 L. pallasii, adult	20-35	100	Survival	46 Isotoma viridis, adult	25	100	Survival
4 Ligidium gracili, adult	20-35	100	Survival	47 Sminthurus viridis, nymph	30	100	Survival
5 Oniscus asellus, adult	14-18	100	Survival	48 adult	7	80-90	Oviposition
6 Porcellio laevis, adult	20-35	100	Survival	49	25	100	Survival
7 Porcellionides pruinosus, adult	20-35	100	Survival	50 Tomocerus vulgaris, adult	25	100	Survival
8 P. scaber, adult	14-35	100	Survival	Diptera			
9 P. spinicornis occidentalis, adult	20-35	100	Survival	51 Fly, green-bottle (<i>Phaenicia sericata</i>), egg	22	100	Development
Acarina				52	37	90-100	Survival
10 Halotydeus destructor, adult	18-26	100	Survival	53 Fly, heel (<i>Hypoderma lineatum</i>)	20-25	0-76	Survival, development
11 Ixodes ricinus, nymph	25-30	90-100	Development	54 Fly, tachinid (<i>Winthemia quadripustulata</i>), pupa	27	73.4	Development
12 I. ricinus, adult	25	100	Oviposition	55 Fly, vinegar (<i>Drosophila melanogaster</i>), pupa	18-19	100	Development
Anoplura				Heteroptera			
13 Louse, horse-sucking (<i>Hematopinus asini</i>), egg	37.8	100	Survival	56 Bedbug (<i>Cimex lectularius</i>), egg	13-35	75-90	Survival
Coleoptera				57 nymph	18	44-77	Development
14 Acilius sulcatus, adult	19	100	Survival	58 Bedbug (<i>C. rotunda</i>), egg	18	93	Survival
15 Beetle, capricorn (<i>Hylotrupes bajalus</i>), egg	16.6	50-60	Development	59 nymph	18	77-93	Development
16	31.5	90-100	Survival, development	60 Cone nose bug (<i>Rhodnius prolixus</i>), egg	17-33	70-90	Survival
17 Beetle, caraboides (<i>Hydrous caraboides</i>), adult	18-20	100	Survival	61 Cotton stainer (<i>Dysdercus cingulatus</i>), egg	35	82-100	Survival
18 Beetle, cigarette (<i>Lasioderma serricornis</i>), egg	32	75	Development	62 Eurygaster mauro, nymph	24-30	80-100	Survival
19 Beetle, clavicorn (<i>Hydrophilus piceus</i>), adult	18-20	100	Survival	63 Palomena prasina, nymph	24-30	80-100	Survival
20 Beetle, confused flour (<i>Tribolium confusum</i>), egg	27	1-75	Survival	Hymenoptera			
21 pupa	27	0-25	Survival	64 Wasp, parasitic (<i>Habrobracon juglandis</i>), egg	16-35	80	Survival
22 Beetle, ladybird (<i>Epilachna corrupta</i>), egg	27	76-81	Survival	65 Wasp, parasitic (<i>Macrocentrus ancylicivorus</i>), adult	26.7	80	Oviposition
23	27	81-100	Development	Lepidoptera			
24 Beetle, oriental (<i>Anomala orientalis</i>), egg	25.5	100	Survival	66 Araschnia levana, pupa	18-20	55-85	Survival
25 Beetle, spider (<i>Ptinus tectus</i>), egg	25	70	Development	67	18-20	100	Development
26 larva	24.7	70	Development	68 Armyworm (<i>Prodenia littoralis</i>), egg	29	90-95	Survival
27 pupa	27	90	Development	69 Cutworm, grain (<i>Agrotis segetum</i>) pupa	17-21	65-85	Development
28 Borer, grain (<i>Rhyzopertha dominica</i>), egg	18.3-38.2	90	Survival	70 Dendrolimus pini, egg	24	80-85	Survival
29 Colymbetes fuscus, adult	15-20	100	Survival	71 Hoffmannophila pseudopretella, egg	15-25	90	Development
30 Eurostus hilleri, egg	20	90	Development	72	13-27	8.5-90	Survival
31 Geotrupes stercorosus, adult	15-19	100	Survival	73 Hornworm, tomato (<i>Protoparce quinquemaculata</i>), pupa	27	0-73.4	Development
32 Laemophloeus minutes, adult	21-25	55-90	Oviposition	74 Moth, cecropia (<i>Hyalophora cecropia</i>), egg	25-21	56-76	Survival
33	17-21	100	Development	75 Moth, lackey (<i>Malacosoma neustria</i>), egg	11-21	90	Survival
34 Melasoma populi, egg	19-25	100	Survival	76 Moth, promethea (<i>Callosamia promethea</i>), egg	20-30	76	Survival
35 adult				77 Moth, webbing (<i>Tineola bisselliella</i>), larva	23.9	75	Development
36 Weevil (<i>Acanthoscelides obtectus</i>) adult	26.6	100	Oviposition	78 Panolis flammea, egg	12-22	65-85	Survival
37 egg	25.2	50-90	Development	79 Samia walkeri, egg	15-25	56-100	Survival
38 Weevil, cowpea (<i>Callosobruchus chinensis</i>), larva	30.4	76	Survival, development	80 Silkworm (<i>Bombyx mori</i>), pre-pupa + pupa	25	7-100	Development
39 Weevil, cowpea (<i>C. maculatus</i>), egg	30	63	Survival, development	81 Tlea polyphemus, egg	30	53-76	Survival
40 Weevil, granary (<i>Sitophilus granarius</i>), adult	20-27.5	60-100	Oviposition				
41 Weevil, rice (<i>Calandra oryza</i>), egg	15-32	90	Survival				
42 Wireworm (<i>Agriotes lineatus</i>), egg	19	100	Survival				
43 larva	20	98-100	Survival				

363. OPTIMAL TEMPERATURES AND HUMIDITIES FOR PHYSIOLOGICAL FUNCTIONS: ARTHROPODS (Concluded)

Several ranges represent extremes reported by different investigators.

Arthropod	Temperature °C	Optimal Humidity %	Function	Arthropod	Temperature °C	Optimal Humidity %	Function
Orthoptera				Siphonaptera			
82 Carausius morosus, egg	15-21	100	Development	90 Flea, oriental rat (Xenopsylla astia), larva	17-35	80-94.8	Survival
83 Grasshopper, clear-winged (Camnula pellucida), egg	27	60-90	Development	91 Flea, oriental rat (X. cheopis), larva	22-35	80-90	Survival
84 Grasshopper, Rocky Mountain (Melanoplus mexicanus), egg	22-37	80-90	Survival	92 Flea (X. brasiliensis), larva	22-27	80-95	Survival
85 Locust, desert (Schistocerca gregaria), egg	30	100	Survival	Thysanoptera			
86 nymph	37.8	55-70	Development	93 Thrips, onion (Thrips tabaci), larva	10-35	75-85	Survival
87 adult	37.8	50-60	Oviposition	Thysanura			
88 Locust, migratory (Locusta migratoria), nymph	32.2-37.8	60-70	Development	94 Firebrat (Thermobia domestica) egg	37	76-85	Survival
89 adult	37.8	60-75	Oviposition	95 nymph	37	84	Development
				96 adult	37	84	Oviposition

364. HEAT EXCHANGES AND ACTIVITY LIMITS IN HOT ENVIRONMENTS: MAN

Basic equation for maximum energy expenditure with heat balance is $M=R+C+E_{max}$, where values are in Cal/sq m body surface per hour; M = body heat production (metabolic rate); R = radiation heat exchange; C = convective heat exchange; E_{max} = maximum evaporative exchange from wet skin. E_{max} is always negative; R and C are positive when heat moves toward the body, and negative when away from the body.

Environment	Exposure Values					Heat Exchange Values			
	Wind Velocity km/hr	Dry Bulb °C	Relative Humidity %	Vapor Pressure ¹ mm/Hg	Clothing Type ²	Convection (C) ³ Cal/sq m/hr	Radiation (R) ⁴ Cal/sq m/hr	Evaporation (E _{max}) ⁵ Cal/sq m/hr	Metabolic Rate Limit (M) ⁶ Cal/sq m/hr
1 Wet tropics, shade	0.9	31	90	11	None	-13	-18	-72	105
2 Wet tropics, shade	0.9	31	90	11	Light	-7	9	-54	52
3 Wet tropics, shade	8.0	31	90	11	None	-42	-18	-150	210
4 Wet tropics, shade	8.0	31	90	11	Light	-21	9	-113	125
5 Wet tropics, sun	0.9	31	90	11	None	-13	112	-72	0
6 Wet tropics, sun	0.9	31	90	11	Light	-7	45	-54	16
7 Wet tropics, sun	8.0	31	90	11	None	-42	112	-150	80
8 Wet tropics, sun	8.0	31	90	11	Light	-21	45	-113	89
9 Desert, sun	0.9	44	10	35	None	32	172	-230	26
10 Desert, sun	0.9	44	10	35	Light	16	69	-172	87
11 Desert, shade	0.9	44	10	35	None	32	42	-230	155
12 Desert, shade	0.9	44	10	35	Light	16	21	-172	135
13 Desert, sun	8.0	44	10	35	None	94	172	-476	210
14 Desert, sun	8.0	44	10	35	Light	47	69	-357	240
15 Desert, shade	8.0	44	10	35	None	94	42	-476	340
16 Desert, shade	8.0	44	10	35	Light	47	21	-357	390
17 Glass forming ⁷	3.7	38	42	21	None	21	255	-220	0
18 Glass forming ⁷	3.7	38	42	21	Light	11	128	-165	26
19 Heated chamber	0.9	115	3	19	Light	267	530	-124	0

/1/ Vapor pressure of skin assumed to be saturated at 35°C (42 mm Hg), minus ambient vapor pressure under prevailing conditions of exposure.

/2/ Clothing type: light = underwear shorts, cotton shirt with sleeves, cotton trousers, shoes and stockings or equivalent, offering 0.5 clo protection (1 clo = insulation maintaining difference of 0.18°C for flow of 1 Cal/sq m/hr; a business suit = 1 clo). /3/ For the nude body, $C=3.7/\sqrt{V}$ (Ta-35 where V is wind speed in km/hr, 35 is assumed skin temperature, and Ta is ambient temperature in °C. Light clothing is assumed to reduce convective exchange by 50%. /4/ For the nude body, $R=3.9 \times 10^{-8} (T_w^4 - T_a^4)$ when T_w and T_a are in degrees absolute and T_a is assumed 308°A. Solar heat load on nude skin is taken as 130 Cal/sq m/hr. Light clothing is assumed to decrease nominal solar heat load by 60% and radiant exchange with hot or cool walls by 50%. /5/ For the nude body $E_{max}=6.3 V^{0.37} \Delta VP$, where V is air movement in km/hr; VP=vapor pressure. For the lightly-clad body, it is assumed that evaporation from the skin is reduced by 50%, but this half is, nevertheless, evaporated from the clothing surface where the heat removed is 50% efficient for skin cooling; this gives an assumed net efficiency of sweating equal to $0.75 \times E_{max}$ determined for the nude body. /6/ Limit for sustained activity. Expenditure of 50-70 Cal/sq m/hr is involved in sedentary activities; 80-110, light physical work; 120-190, moderate work; 200-290, moderately hard work; 300-390, hard work; 400 and above, very hard work tolerated for prolonged periods only by fit, trained subjects. /7/ Radiant heat.

365. TEMPERATURE CHARACTERISTICS: VARIOUS HOMEOTHERMIC ANIMALS

+ = present; - = absent.

Animal	Rectal Temperature			Critical Air Temperature ¹		Temperature Regulating Mechanisms			Thermoneutrality Zone ² °C
	Normal °C	Min °C	Max °C	Low °C	High °C	Sweating	Shivering	Panting	
1 Man	37	22	44	17-22	32	+	+	-	23-34.5
2 Cat	37.2-39	17	42		32.2	-	+	+	10-30
3 Cow, Brahman	38		41.1		32	-		+	10-27
4 Cow, dairy	38-39		42.8	-40	21-27	-		+	4.4-15.6
5 Dasyurus	36.3		40		35-40	-		+	24-30
6 Dog	39	17	42.8	-40	29	-	+	+	-40 to 30
7 Donkey	36-38					+			
8 Echidna	28-29	25.5	39-40		35	-	+	-	26-37
9 Elephant	35.9-36.7					-	+		
10 Goat	40								13-21
11 Guinea pig	38.5-39.9	21		-15	29.5			+	30-31
12 Hamster	37	2.2						+	
13 Horse	38					+	+		
14 Marmot	34-39	3	42.1	27.5	30	-	-		28
15 Monkey	38	20	42.7		30-32	+			27-30
16 Mouse	35.2-37.8	12.5		13.14	31.5				30-33
17 Platypus	32.5	25.5	35.3	15	35-40	-	+	-	22-35
18 Rabbit	39.6	20	41.7	-7	28-30	-		+	-5 to 30
19 Rat	35.8-37.6	15-16	43	-7	28.5	-	+	-	28-29
20 Sheep	38		42		41-43	+		+	25-27
21 Sloth	33-34.4	20	40	15	35		-	+	
22 Squirrel	35.5-38.4	0-2	42.3						7-37
23 Swine	38-39.6		41.7		29.5	-		+	
24 Chicken	40-42	25-27	45	-34	32.2	-	+	+	16-35
25 Pigeon	42-43	20	47	-40					26-37

/1/ Air temperature at which the first indication of a change in rectal temperature occurs in the unanesthetized animal. /2/ Range of air temperature over which the metabolic rate is lowest and constant in the unanesthetized animal.

366. HEAT PRODUCTION UNDER CONTROLLED ENVIRONMENTAL CONDITIONS: VARIOUS ANIMALS

Animal	Temperature °C	Heat Production Cal/sq m/24hr ¹
1	15.3	1254
2	19.7	1043
3 Rat	25.0	826
4	30.0	744
5	34.0	1178
6	15.1	1050
7	20.0	913
8 Guinea pig	24.8	784
9	29.8	601
10	35.3	716
11	14.6	1741
12	20.0	1037
13 Mouse	24.9	953
14	29.9	879
15	35.3	1009
16	18.0	1.2 ²
17 Reptile	26.0	2.3 ²
18	32.0	3.2 ²

/1/ Lines 1-15. /2/ Cal/kg/24 hr.

367. EFFECTS OF ENVIRONMENTAL TEMPERATURE CHANGE: MAN, DOMESTIC ANIMALS

Values are for resting state.

Animal	Variable	Increase of Environmental Temperature			Decrease of Environmental Temperature		
		Single Exposure Response		Repeated or Continued Exposure	Single Exposure Response		Repeated or Continued Exposure
		General	15-20°C Inc.		General	15-20°C Dec.	
1	Blood volume	Increase		Increase	Decrease		Decrease
2	Cardiac output	Increase		Return toward normal	Decrease		Return toward normal
3	Food intake	Decrease	Variable	Decrease	Increase	Variable	Increase
4	Heart rate	Increase	5/min	Return toward normal	Decrease	-5/min	Return toward normal
5	Heat production	0 or slight + ¹		Some decrease	Increase	50 to 100 Cal ²	Increase
6	Manual skill	Deteriorates		Return toward normal	Deteriorates		Return toward normal
7	Packed cell volume	Slight decrease	-2 to 3%	Decrease	Slight increase	2 to 3%	Increase
8	Rectal temperature	Increase	0.5 to 1°C	Return toward normal	Decrease	-1 to 2°C	Return toward normal
9	Skin temperature	Increase	10 to 15°C	Return toward normal	Decrease	-10 to 15°C	Return toward normal
10	Output of urine	Decrease	-200 to 500 ³	Sustain low level	Increase	200 to 500 ³	Sustain high level
11	Blood flow ⁴	Decrease		Return toward normal	Increase		Return toward normal
12	Water intake	Increase	400 ³	Sustain high level	Decrease	-400 ³	Sustain low level
13	Food intake	Decrease	to 60% normal	Increase			Sustain high level
14	Heart rate	Decrease	-15/min	Sustain low level	Increase	5 to 10/min	Sustain high level
15	Heat production	Decrease		Lasting decrease	Increase	10 Cal/kg/da	Sustain high level
16	Rectal temperature	Increase	-1 to 2°C	Return toward normal	0 or slight + ⁵		Normal level
17	Respiration rate	Increase	20 to 30/min	Sustain high level	Decrease	-10 to 20/min	Sustain low level
18	Food intake	Decrease	-15 to 30%	Return toward normal	Increase		
19	Rectal temperature	0 or slight + ⁵		Normal level	0 or slight + ⁵		
20	Respiration rate	0 or slight + ⁵		Normal level	0 or slight + ⁵		
21	Heart rate	Increase	8/min				
22	Rectal temperature	Increase	1°C				
23	Respiration rate	Increase	100-150/min				
24	Food intake	Decrease		Continued low level			
25	Heart rate	Increase	10/min				
26	Rectal temperature	Increase ²	2 to 3°C				
27	Respiration rate	Increase	150-200/min				
28	Water intake	Increase		Continued high level			

/1/ No change or slight increase. /2/ Per sq m/hr. /3/ ml/da. /4/ Visceral. /5/ Little or not change.

368. EFFECTS OF HYPOTHERMIA: MAMMALS

Part I: PHYSIOLOGICAL VALUES

A = anesthetized; N = unanesthetized; C = curarized; R = restrained.

State	Variable	Body Temperature, °C					State	Variable	Body Temperature, °C				
		20	25	30	35	37-39			20	25	30	35	37-39
Man													
1	N Metabolic rate, Cal/sq m/hr					200 60	33	R O ₂ consumption, cu mm/min/g		13	25	35	20.8
2	A Metabolic rate, Obs/Est		1.58	1.46	2.82	1.00	34	R Ventilation rate, % of normal		75	125	170	100
3	A Respiratory volume, L/min		9.6	12.7	19.4	8.7	Hamster						
4	A Respiratory quotient		0.68	0.75	0.77	0.88	35	N Heart rate, min	190	260	330	380	
5	A Blood HbO ₂ capacity, mM/L		10.8	9.73	9.2	8.0	36	N O ₂ consumption, ml/kg/min	38	50	56		
6	A Blood HbO ₂ content, %		93.0	96.7	95.9	97.2	37	N Respiratory rate, min	120	122	110	90	
7	A Blood total CO ₂ , mM/L		20.0	13.5	18.6	21.5	38	Perfused heart rate, min	47	73	105	155	
8	A Blood pH		7.22	7.31	7.29	7.39	Rabbit						
9	A Blood pCO ₂ , mm Hg		45.2	27.4	42.2	40.7	39	C O ₂ consumption, ml/kg/hr		200	300		600
10	Heart rate, sinus-atrium, min ¹	40	70	100	145	157	40	N Respiratory rate, min	60	20-40 ⁵			200
11	Ventricle, min ¹	10	20		40		41	N Heart rate, min	20-40	40-70			200
Cat													
12	N Heart rate, min	50	117	180	220		42	A Plasma volume, ml/kg			28		44
13	N Respiratory rate, min	0	47	55	60		43	A Hematocrit, %			44		41
14	Perfused heart rate, min	53	100	145			44	A Blood volume, ml/kg			50		73
Dog													
15	A O ₂ consumption, ml/kg/hr ²	90	160	270	390	430	45	A Plasma protein, g/100 ml			6.0		4.9
16	A O ₂ consumption, ml/kg/hr ³	72	325	480	340	380	46	A Thiocyanate space, ml/kg			170		245
17	A Heart rate, min	30	70	125	170	155	47	A Circulating RBC volume, ml/kg			22		29
18	A Cardiac output, ml/kg/min	18				135	48	A Total circulating plasma protein, g/kg			1.7		2.1
19	A Mean arterial pressure, mm Hg	70	110	120	130	125	49	A Extravascular CNS space, ml/kg			140		200
20	A Blood viscosity ⁴	8.78	7.23	5.52	4.42	3.50	50	Isolated atrium rate, min	30	65	100	145	
21	A Hematocrit, % ⁴	60.6	56.9	54.2	54.1	43.9	Rat						
22	A Arterial O ₂ content, vol % ⁴	21.0				18.6	51	N O ₂ consumption, ml/kg/min	8	17	25		
23	A Coronary vein saturation, % ⁴	29.0				28.4	52	A Heart rate, min	120	195	270	350	
24	A Coronary vein, O ₂ content, vol % ⁴	8.3				4.8	53	R Heart rate, min	110	200	300	420	460
25	A Coronary vein, pO ₂ , mm Hg ⁴	8.6				22.2	54	R A-V conduction time, sec	0.08	0.06	0.045	0.04	
26	A Coronary artery-vein diff., vol % ⁴	12.7				13.8	55	A Respiratory rate, min	18	48	68	66	
27	A Duration of systole, sec	0.60	0.33	0.20	0.16	0.15	56	A Mean arterial pressure, mm Hg	50	130	140	140	
28	A P-R interval, sec	0.22				0.10	57	A Liver, glycogen, %					4.10
29	A Q-R S duration, sec	0.09				0.05	58	A Blood glucose, mg %					138
30	A Q-T interval, sec	1.04				0.25	59	Perfused heart rate, min	73	120	165	225	
31	Perfused heart rate, min						60	Tissue slices, dry					
Guinea pig													
32	R Heart rate, min		125	215	300		61	Cerebral cortex, ml/g/hr	2.7	3.8	5.4	7.9	10.2
							62	Liver, ml/g/hr	2.3	4.0	5.9	8.3	9.8
							63	Heart ventricle, ml/g/hr	3.3	5.1	7.2	8.3	10.0
								Skeletal muscle, ml/g/hr	1.2	1.50	1.9	2.4	3.1

/1/ Embryo. /2/ Shivering absent; arterial O₂ saturation 90-100%. /3/ Pattern varies in different animals. /4/ Arterial O₂ saturation 95% and above. /5/ "Pseudo-hibernating" state.

368. EFFECTS OF HYPOTHERMIA: MAMMALS (Concluded)

Part II: LOCAL COLD INJURY

Mammals	Exposure		Results	Mammal	Exposure		Results
	Medium	Conditions °C; min			Medium	Conditions °C; min	
1 Man, face	Air	-32.5	Cooling rate 2000 Cal/sq m/hr. Average time to freeze: 102 sec.	9 Rabbit, foot ⁴	Liquid ²	-55; 2	Edema and gangrene; 80% lost all toes.
2 forearm	Copper bar		Highest temp at which freezing occurred: -2.2 to -4.6°C. Super-cooling to -20.4°C observed without freezing.	10 (concluded)		-55; 3	Edema and gangrene; 69% lost complete exposed area.
3 Rat, foot ¹	Liquid ²	-22	Average time to freeze: 38 sec.	11 leg ⁵	Alcohol	+5; 30	No edema; slight atrophy.
4		-25	Average time to freeze: 11 sec.	12		0; 30	Little edema; moderate atrophy and temporary paralysis.
5 Rabbit, ear ³	Liquid ²	-55; 0.25	Gangrene, loss of 80% exposed area.	13		-5; 30	Edema, atrophy, temporary paralysis.
6		-55; 0.5	Gangrene, loss of 80% exposed area.	14		-10; 30	Edema, atrophy, paralysis, loss of sensation. Muscle necrosis in 50%.
7		-55; 1+	Edema, gangrene, complete loss of exposed area.	15		-12; 30	Edema, marked muscle necrosis.
8 foot ⁴	Liquid ²	-55; 1	Edema, no gangrene; 92% of animals showed no loss of tissue, but moderate induration.	16		-15; 30	Edema, muscle and skin necrosis.
				17		<-15; 30	Usually complete loss of exposed part.

/1/ Pentobarbital anesthesia; no hair removed. /2/ 150 ml 95% alcohol added to one liter 50% ethylene glycol. /3/ Dial anesthesia; no hair removed. /4/ Dial anesthesia; hair removed by close clipping; immersed to tuberosity at base of 5th metatarsal. /5/ Chemical depilation; no anesthesia; covered with layer of wool fat and rubber boot; immersed to knee.

369. EFFECTS OF HYPOTHERMIA: MAN

Part I: EFFECTS OF BRIEF EXPOSURES TO LOW TEMPERATURES

Variable	Before Exposure, Air 24°C	After Exposure ¹ , Air -40°C	Before Exposure, Air 23°C	After Exposure ² , Water 6°C
1 Rectal temperature, °C			37.5	36.5
2 Skin temperature, °C			29.4 ³	8.3 ³
3 Respiratory volume, L/min			9	38.2
4 Oxygen consumption, L/min			0.34	1.74
5 Respiratory quotient			0.81	1.01
6 Metabolic rate, Cal/hr			97	523
7 Heart rate, per min			75	95
8 Systolic pressure, mm Hg			125	144
9 Diastolic pressure, mm Hg			80	93
10 Leucocytes, per cu mm	7000	8300	6600	7950
11 Neutrophils, per cu mm	3500	5000	3370	5720
12 Lymphocytes, per cu mm	2500	2700	2570	1270
13 Monocytes, per cu mm	520	530	265	795
14 Eosinophils, per cu mm	120	105	265	160
15 Basophils, per cu mm	42	40	130	0
16 Hematocrit, %	47.5	49.5	52	50
17 Hemoglobin, g/100 ml blood	16.3	17		
18 Blood, specific gravity	1.057	1.059		
19 Serum protein, g/100 ml	6.8	7.4	5.9	5.9
20 Ascorbic acid, RBC, mg/100 ml	1.7	2		
21 Ascorbic acid, serum, mg/100 ml	1	1.6		
22 Serum chloride, mEq/L	109	100		
23 Serum sodium, mEq/L	144	140		
24 Serum potassium, mEq/L	6.8	8.2		
25 Urine volume, ml/hr	40	100		

/1/ 4 hours exposure. Clothing: U.S. Army Quartermaster winter issue. /2/ 32-49 minutes after immersion to neck. /3/ Mean temp of immersed parts.

Part II: SURVIVAL TIME FOR IMMERSION IN COLD WATER

Probability of Survival		Duration of Immersion and Range of Water Temperature							
		From	hr	°F	°C	To	hr	°F	°C
1	Few, if any survivors		1.2	30	-1.1		3.0	46	7.8
2	50% survive		0.5	35	1.7		2.3	52	11.1
3	All survive		0.7	50	10.0		2.0	70	21.1

Part III: ESTIMATES OF TIME (HOURS) FOR MAXIMUM SAFE LOSS OF STORED BODY HEAT UNDER COLD CONDITIONS

80 calories is estimated safe loss of stored body heat by an adult. Effectiveness of clothing insulation, measured under static conditions, is reduced by penetrating force of wind.

Air Move - ment ft/min	Effective Insulation clo ¹	Air at 0°C			Air at -40°C		
		Body at:			Body at:		
		Rest	3 mi/hr	4 mi/hr	Rest	3 mi/hr	4 mi/hr
1 100	1	0.73	1.90	Infant ²	0.27	0.34	0.44
2 4000	1	0.58	1.10	11.20	0.22	0.27	0.34
3 100	2	1.17	Infant ³	Infant ²	0.53	0.90	2.10
4 4000	2	1.15	Infant ³	Infant ²	0.48	0.78	1.60
5 100	3	3.80	Infant ³	Infant ²	0.85	2.50	Infant ⁴
6 4000	3	3.30	Infant ³	Infant ²	0.80	2.20	Infant ⁴
7 100	4	10.80	Infant ³	Infant ²	1.30	57.0	Infant ⁴
8 4000	4	8.80	Infant ³	Infant ²	1.20	21.0	Infant ⁴

/1/ 1 clo = insulation maintaining difference of 0.18°C for flow of 1 Cal/sq m/hr. /2/ Complete protection given by 0.6-1.1 clo. /3/ Complete protection given by 1.2-1.7 clo. /4/ Complete protection given by 2.6-2.7 clo.

Part IV: PREDICTED LOWEST AMBIENT TEMPERATURES FOR PROLONGED THERMAL EQUILIBRIUM AND TOLERABLE EXPOSURE

Values are approximations for young adult males and, except where indicated by an asterisk, are from actual observations at Harvard Fatigue Laboratory or Quartermaster Climatic Research Laboratory. Ambient temperature, $T_a = 5.56T_s - (I \times H)$, where 5.56 is applicable constant for the units of choice; T_s is mean skin temperature, assumed to be 32°C; I is total insulation against heat loss by convection and radiation in clo units (1 clo = insulation maintaining difference of 0.18°C for flow of 1 Cal/sq m/hr); H is total heat available for loss from body by convection and radiation.

Activity	Environment	Nude		Business Suit (1 clo)		Arctic Clothing (4 clo)	
		Equilibrium °C	1 hr ² °C	Equilibrium °C	1 hr ² °C	Equilibrium °C	1 hr ² °C
1 Sitting ³	Calm, shade, sea level	27	17	21	-4	0	-67
2	Wind, 8 km/hr (5 mi/hr); shade, sea level	30	26	24	4	4	-55
3	Wind, 40 kg/hr (25 mi/hr); shade, sea level	31	28	26	12	10	-36
4	Wind, 8 km/hr (5 mi/hr); sunshine ⁴ , sea level	23	19	17	-1	-7	-48
5	Wind, 8 km/hr (5 mi/hr); sunshine, 6 km (20,000 ft) above sea ⁵	13*	8*	4*	-19*	-32*	-111*
6 Standing, light work ⁶	Wind, 8 km/hr (5 mi/hr); shade, sea level	29	25	20	4	-6	-56
7 Walking, 6 km/hr ⁷	Wind, 8 km/hr (5 mi/hr); shade, sea level	25	20	10	-3	-34	-72*
8 Running, 10 km/hr ⁸	Wind, 8 km/hr (5 mi/hr); shade, sea level	14	10	-15	-27	-104*	-138*

/1/ In simplest equilibrium state, H is taken as 0.75 M, where M is limit of metabolic rate for sustained activity, expressed as Cal/sq m/hr. (Approximately three-quarters of the heat produced is available for loss by convection and radiation.) /2/ Heat available for loss is 0.75 M+80. (Withdrawal of 80 Cal/sq m from the total body mass can be tolerated with discomfort.) /3/ M=50. /4/ Absorbed solar heat (S) becomes part of H in basic formula. S=130 for nude body, 13.75 for business suit, and 16 for arctic suit. /5/ S increased 70% over values of Fn 4 (greater intensity of solar radiation at altitude). /6/ M=80. /7/ N=180. /8/ M=440.

370. TEMPERATURE RANGES FOR EGG-LARVA DEVELOPMENT: HELMINTHS

Part I: TREMATODES

Helminth		Stage	Medium	Temperature, °C			Development
				Optimum	Maximum	Minimum	
1	<i>Clonorchis sinensis</i>	Metacercaria	Tyrod's solution, plus rabbit serum.	37			Survived 2 weeks. No development.
2	<i>Diplostomum flexicaudum</i>		Tyrod's solution, plus lenses from eyes of vertebrates.	Room			Survived and active 52 days. No growth.
3	<i>Fasciola hepatica</i>	Egg	Water.	25	37	5-13	Hatched in 14 days at optimum temperature.
4		Larval stages	In snail.	25			Infection to mature cercariae 38-42 days.
5						16-19	Infection to mature cercariae 57 days.
6	<i>Gynaecotyla adunca</i>	Metacercaria	1% sea water.	40			Matured sexually within 80 hours. Survived 8 days.
7	<i>Microphallus opacus</i>		Ringer's solution and normal saline.	37			Eggs in uterus within 12 hours. Survived 4-5 days.
8							12	Developed slowly.
9	<i>Posthodiplostomum minimum</i>		Dilute Tyrod's solution, plus chicken serum, plus yeast extract.	39			Matured but eggs infertile.
10					5-7	Survived 1 month. No growth.	
11	<i>Schistosoma japonicum</i>	Egg	Water.	10-30	37	2	Range for hatching.
12	<i>Zygocotyle lunata</i>	Metacercaria	Water and a wide variety of hosts.			-13 to 7	Metacercariae withstood freezing and thawing 15 hours to 10 days.
13				Body			Matured in bird, mammal.

Part II: CESTODES

	Helminth	Stage	Medium	Temperature, °C			Development
				Optimum	Maximum	Minimum	
1	<i>Crepidobothrium lönnbergi</i>	Immature worm	Hottinger's broth (modified).	Room			Increased length. Survived 32 days.
2	<i>Diphyllobothrium latum</i>	Egg	Washed feces and tap water.			-10	Eggs non-viable after 48 hours.
3		Plerocercoid	Nutrient agar, plus hog serum.	37.5		15	Eggs remained viable 8 months.
4	<i>Echinococcus granulosus</i>	Scolex	Hydatid fluid, plus horse or ox serum.	37-39	42-44	-4 to 0	Increased size.
5							Volume of bladder increased. Survived 31 days.
6	<i>Ligula intestinalis</i>	Plerocercoid	Peptone broth.	40		Room	Little activity. Did not mature.
7	<i>Schistocephalus solidus</i>			16-19			Active. Normal appearance for 300 days. No eggs.
8				40			Matured sexually within 48-60 hours. Survived 4-6 days.
9	<i>Taenia crassicolis</i>	Blastocyst	Locke's solution, plus chick embryo extract, plus horse serum.	37.5			Developed to invagination of scolex. Survived 35 days.
10	<i>T. saginata</i>	Egg	Sodium hypochlorite or pepsin-pancreatin, physiological saline.	39			Eggs hatched within 4½ hours.
11						2-5	Remained viable for 13½ weeks.

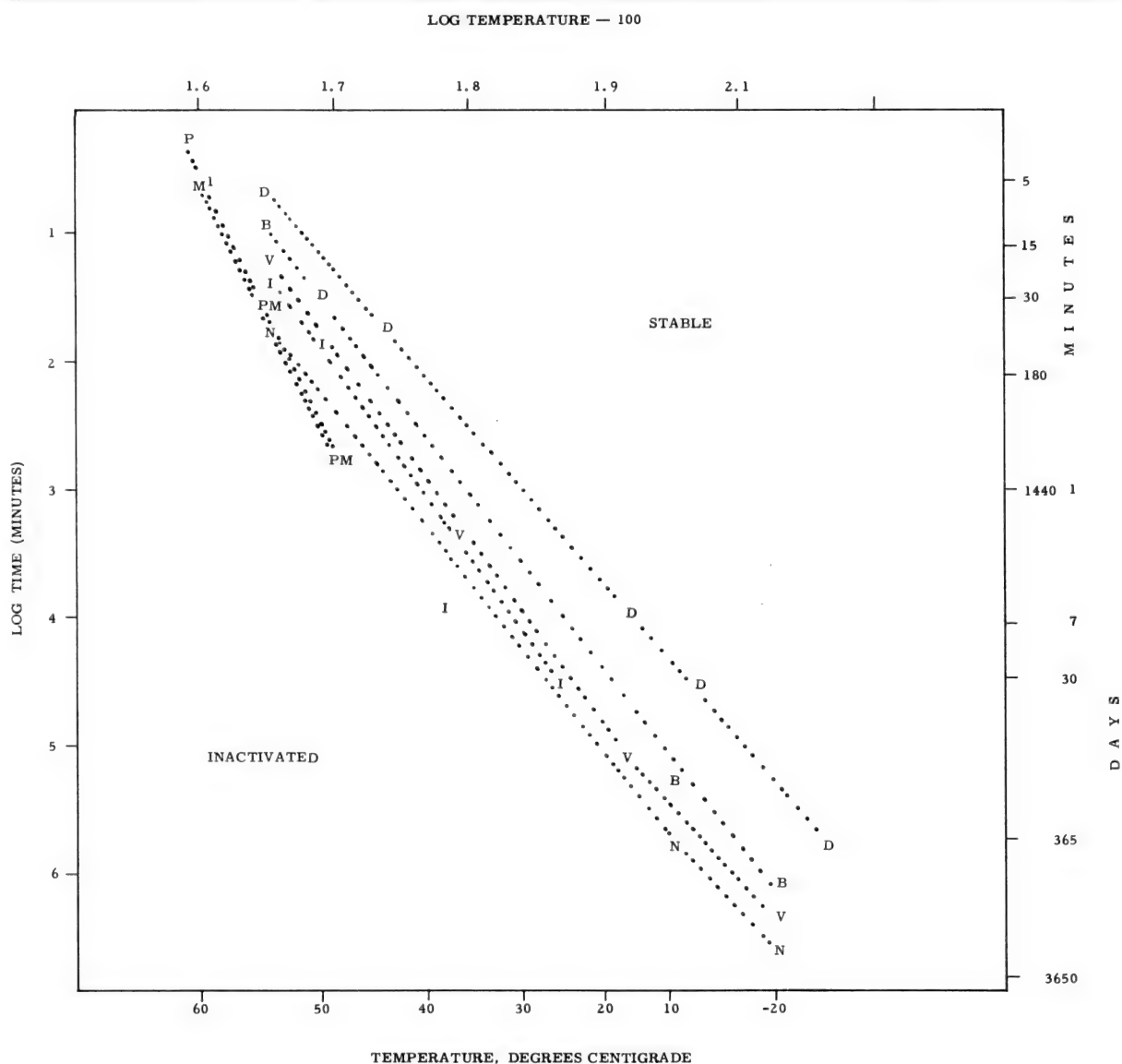
Part III: NEMATODES

	Helminth	Stage	Medium	Temperature, °C			Development
				Optimum	Maximum	Minimum	
1	Ancylostoma caninum	Egg	Bacteriological agar, plus	30	40	12	Range of hatching.
2		Larva	Bacillus coli.	30	37	15	Development range.
3	Ascaris lumbricoides var. suis	Egg	Tyrod's solution.	38-40			Hatched.
4		Larva	Distilled water.	Room			Matured 5 weeks.
5	Dirofilaria immitis	Larva	Dextrose dog serum.	37			Little development. Survived 3-8 days.
6			Bacto-proteose-peptone 1.0%; NaCl, 0.85%; glucose, 0.5%.			12	Increased size 2½ times. Survived 2 weeks in ice chest.
7	Eustrongylides ignotus			20			Survived 30 months. Infectivity not established.
8	Haemonchus contortus	Egg Larva	Rabbit kidney, plus liver extract agar, plus ground yeast.	22-27			Eggs hatched 14 days; infective larvae within 26 days.
9	Necator americanus	Egg Larva	"Most favorable conditions."	25-30	37-40	8-10	Range for egg-larvae development.
10	Neoaplectana glaseri	Egg Larva Adult	Veal infusion broth, plus raw liver extract.	21-26	31.8	0	Cycle completed. Survived 44 months.
11	Nippostrongylus muris	Egg	Water.	22-30	35	0-5	Hatched at optimum within 24 hours.
12	Trichinella spiralis	Larva	Simm's solution, plus chicken plasma, plus chick embryo extract.	37			Several molts completed. Few survived 9 days.
13	Trichuris trichiura	Egg	Water.	30	54	-9 to -12	Development range.

371. TEMPERATURES FOR INACTIVATION AND SURVIVAL: ANIMAL VIRUSES

The capacity of animal viruses to infect susceptible cells is destroyed more and more rapidly as the environmental temperature is increased. Thermal inactivation of the infectivity of a virus may be expressed in several ways, as the highest temperature at which there is detectable virus after a selected interval of time, as the longest time at which virus is detectable at a given temperature, or as the number of entropy units. The first two values are dependent on the quantity of virus (number of LD₅₀ per ml) in the initial preparation and all three measurements of inactivation depend upon the inherent resistance of the virus particles in the preparation. Substrains composed of heat resistant mutants have been selected for several viruses, and heat resistant and susceptible wild strains are recognized for these and other viruses. Many factors, some well known, modify the thermal inactivation of a virus, e.g., condition of the virus whether wet (inactivation being rapid in a fluid medium) or dry (inactivation of lyophilized virus being slow), the amount of available oxygen (reducing agents increasing stability), the pH of the suspending medium (inactivation being more rapid in basic or acidic preparation than in those in the neutral range), the presence of divalent and monovalent ions (the sodium ion decreasing stability), and admixture with or adsorption to proteins. Most available information has been obtained by using crude preparations in which the contributions of modifying factors are unknown. Tabulation of such data may not, therefore, be meaningful. A figure, therefore, depicting the stability of representative animal viruses in a crude preparation at several temperatures and for varying periods, may be of use to investigators concerned with virus storage, insofar as it suggests the pattern of time-temperature points at which inactivation may occur. On the basis of studies with reasonably pure preparations heat inactivation of virus follows a first order of kinetics.

B = bronchitis; D = distemper; I = influenza A; M = myxomatosis; N = Newcastle disease; P = poliomyelitis; V = vesicular stomatitis.



372. SURVIVAL TIME OUTSIDE THE HOST: PLANT VIRUSES

Common names of viruses are taken largely, but not exclusively, from "Common Names of Viruses Used in The Review of Applied Mycology," Rev. Appl. Mycol. 24:513, 1946. Latin names follow the system of virus nomenclature used by Holmes, "The Filterable Viruses," Williams and Wilkens, Baltimore, 1948.

Virus	Plant Source of Virus	Conditions of Survival		Survival Time	Virus	Plant Source of Virus	Conditions of Survival		Survival Time
		Medium	Temp °C				Medium	Temp °C	
1 Alfalfa mosaic (Marmor medicaginis)		Plant juice	Room	8-<9 da	50 Pea, mottle (concluded)	Pea	Dried tissue	25	31 da
2	Tobacco	Plant juice	4	7 da	51 Pea streak, American	Pea	Plant juice	20	24-<48 hr
3	Tobacco	Buffer	4	28 da	52 Pea streak, New Zealand (Marmor iners)	Pea	Plant juice	Room (?)	41 da
4	Cucumber	Dry tissue	1-2	303 da	53 Pea streak, Wisconsin	Pea	Plant juice	22	16-<32 da
5 Alsike clover mosaic (M. fastidiens)	Pea (?)	Plant juice	20	24-<48 hr	54	Pea	Plant tissue	<0	10-40 da
6 Aster yellows (Chlorogenus callistephi)	Vector	Insect juice	0	24-<48 hr	55 Pea stunt	Pea	Plant juice	22	24-<48 hr
7	Vector	Insect juice	25	2-<3 hr	56 Pea wilt (M. repens)	Pea	Plant juice	25	31 da
8 Bean mosaic (Marmor phaseoli)	Bean	Plant juice	Room	14-<24 hr	57 Potato aucuba mosaic (M. aucuba)	Pea	Dried tissue	25	31 da
9 Bean pod mottle (M. valvularum)	Bean	Plant juice	18	62-<93 da	58	Potato	Plant juice	15	3-<4 da
10 Bean red node (Annulus orae var. phaseoli)	Bean	Plant juice	18	24-<48 hr	59 Potato mild mosaic (M. solani)	Potato	Plant juice	Room	2-4 hr
11	Bean	Plant juice	20-25	30-<90 da	60 Potato mottle (Annulus dubius)	Potato	Plant juice	Room	4-5 mo
12	Bean	Dried tissue	Room (?)	7 mo	61	Nicotiana rustica	Plant juice	16-20	60-360 da
13 Bean southern mosaic (Marmor laesiofaciens)	Bean	Plant juice	18	32 wk	62	Potato	Dried tissue	Room (?)	363 da
14 Bean yellow dot (M. medicaginis var. phaseoli)	Bean	Plant juice	18	72-<96 hr	63	Tobacco	Dried tissue	Room (?)	386 da
15	Bean	Dried tissue	8	1 yr	64	Potato	Dried tissue	Room (?)	50 da
16 Bean yellow mosaic	Bean	Plant juice	Room (?)	28-<32 da	65 Potato spindle tuber (Acrogenus solani)	Potato	Plant juice	10	<48 hr
17 Bean yellow stipple (M. flavopunctum)	Bean	Plant juice	18	5-<6 da	66	Potato	Dried tissue	Room	7-<17 da
18	Bean	Dried tissue	18	80 da	67 Potato vein banding (Marmor epsilon)	Tobacco	Plant juice	Room (?)	5-<6 da
19 Bergerac ringspot (Annulus bergerac)		Plant juice	Room	9-<12 da	68	Tobacco	Plant juice	20-22	6-18 da
20 Broadbean mottle	Broadbean	Plant juice	15	<20 da	69	Potato	Dried tissue	Room (?)	50 da
21 Brome-grass mosaic (Marmor graminis)	Bromus inermis	Dried tissue	Room	306 da	70	Tomato	Dried tissue	Room (?)	17 da
22 Carnation mosaic	Carnation	Plant juice	Room (?)	7-<42 da	71	Tobacco	Dry tissue	1-2	420 da
23 Cauliflower mosaic (M. crucifera-rum)	Cauliflower	Plant juice	22	14-<15 da	72 Potato yellow dwarf (Aureogenus vastans)	Nicotiana rustica	Plant juice	25	2-1/2-12 hr
24 Celery mosaic (M. umbellifera-rum)	Celery	Plant juice	Room	6-<7 da	73	Nicotiana rustica	Leaves	-14	1-<7 mo
25 Clover red vein mosaic (M. trifolii)	Vicia faba	Plant juice	Room	2-<3 da	74	Nicotiana rustica	Partly purified	0	4 wk
26 Cowpea mosaic (M. vignae)	Cowpea	Plant juice	20-25	48-<72 hr	75	Nicotiana rustica	Dried leaves	Room	<1 wk
27 Cowpea mosaic (Trinidad)	Cowpea	Plant juice	20	20 da	76 Primula mosaic	Primula	Plant juice	22	24-<48 hr
28 Cucumber green-mottle mosaic	Cucumber	Plant juice	Room (?)	1 yr	77 Radish mosaic (Marmor raphani)	Radish	Plant juice	22	14-<16 da
29 Cucumber mosaic (M. cucumeris)	Cucumber	Plant juice	Room	2-5 da	78 Rose mosaic (M. rosae)	Cowpea	Plant juice	Room	30-<60 min
30	Sweet corn	Dry tissue	23	58 da	79	Cowpea	Plant juice + buffer	Room	6-<24 hr
31	Sweet corn	Dry tissue	1-2	669 da	80 Sugar beet curly top (Ruga verrucosans)	Sugar beet	Plant juice	Room	7-14 da
32 Dahlia mosaic (M. dahliae)	Verbesina encelioides	Plant juice	18	28-<35 da	81	Sugar beet	Ext. alc. precip.	Room	28-<35 da
33 Delphinium ringspot (Annulus delphinii)	Cucumber	Plant juice	Room	4-<5 da	82	Sugar beet	Dried phloem exudate	Room	10 mo
34 Dodder latent mosaic (Marmor secretum)	Pokeweed	Plant juice	24	48-<72 hr	83	Sugar beet	Dry tissue	Room	8 yr
35 False garlic mosaic (M. angustum)	False garlic	Plant juice	Room	17-<20 da	84 Sugar beet mosaic (Marmor betae)	Sugar beet	Plant juice	21	24-<48 hr
36	False garlic	Plant juice	4-5	52 da	85 Sugarcane mosaic (M. sacchari)		Plant juice	Room (?)	557 da
37	False garlic	Dried tissue	Room	40-<43 da	86 Sunn hemp mosaic, southern		Plant juice	Room	42-<48 hr
38 Hyacinth bean enation mosaic	Hyacinth bean	Plant juice	Room	6 yr	87 Tobacco broad ringspot (Annulus apterus)	Tobacco	Plant juice	Room	16 da
39 Lettuce mosaic (M. lactucae)	Lettuce	Plant juice	Room	48-<72 hr	88	Tobacco	Plant juice	4	5-<13 da
40 Muskmelon mosaic (M. melonis)	Muskmelon	Plant juice	Room	74-250 hr	89 Tobacco etch (Marmor erodens)	Tobacco	Plant juice	Room	301 da
41	Muskmelon	Dried juice	Room	72-298 hr	90	Tobacco	Dry tissue	1-2	Many yr
42 Narcissus mosaic	Narcissus	Plant juice	21-24	72-<96 hr	91 Tobacco mild dark-green mosaic (M. constans)	Tobacco	Plant juice	5±2	Many yr
43 Oat mosaic (M. terrestre)	Oat	Dry tissue	1-2	177 da	92	Tobacco	Dried tissue	Room	15 mo
44 Onion yellow dwarf (M. cepae)	Onion	Plant juice	29	112 hr	93 Tobacco mosaic (M. tabaci)	Tobacco	Plant juice	Room	52 yr
45	Onion	Drying leaves	29	100-<110 hr	94	Tobacco	Dried leaves		2 da
46 Orchid mosaic	Cymbidium	Plant juice	Room	7 da	95 Tobacco mottle	Tobacco	Plant juice	Room (?)	About 20 da
47 Pea enation mosaic (M. pisi)	Pea	Plant juice	Room	4-<5 da	96 Tobacco necrosis (M. lethale)	Tobacco	Plant juice	21±	6 mo
48 Pea mosaic virus (M. leguminosarum)	Bean	Plant juice	22	2-<3 da	97	Tobacco	Dry alc. precip.	Room	6 mo
49 Pea mottle (M. efficiens)	Pea	Plant juice	25	31 da	98	Tobacco ringspot (Annulus tabaci)	Ab. alcohol	Room	6 mo
					99	Various susceptibles	Plant juice	Room	1-6 da
					100	Tobacco	Dry tissue	1-2	393 da

372. SURVIVAL TIME OUTSIDE THE HOST: PLANT VIRUSES (Concluded)

Common names of viruses are taken largely, but not exclusively, from "Common Names of Viruses Used in The Review of Applied Mycology," Rev. Appl. Mycol. 24:513, 1946. Latin names follow the system of virus nomenclature used by Holmes, "The Filterable Viruses," Williams and Wilkins, Baltimore, 1948.

Virus	Plant Source of Virus	Conditions of Survival		Survival Time	Virus	Plant Source of Virus	Conditions of Survival		Survival Time
		Medium	Temp °C				Medium	Temp °C	
101 Tobacco ringspot (Annulus tabaci var. cyamopsidis)	Guar	Plant tissue	5	2-4 mo	106 Tomato spotted wilt (Lethum australiense)	Tobacco	Plant juice	Room	3-1/2-4 hr
102 Tobacco streak (A. orae)	Tobacco	Plant juice	22	24-36 da	107 Tulip breaking (Marmor tulipae)	Lily	Plant tissue	Room (?)	2-6 da
103 Tomato aspermy	Tomato	Plant juice	20.5-21.5	24-48 hr	108 Turnip mosaic virus (M. brassicae)		Plant juice	20	3-8 da
104 Tomato black ring	Tomato	Plant juice	Room	7 da	109 Vigna catjang mosaic	Vigna	Plant juice	24	9-15 da
105 Tomato bushy stunt (Marmor dodecahedron)		Plant juice	Room	28-33 hr	110 Wheat mosaic (M. tritici)	Wheat	Dry tissue	1-2	290 da
					111 Wheat streak (M. virgatum)	Wheat	Dried tissue	Room	34-40 da

373. EFFECT OF TEMPERATURE ON GROWTH AND SURVIVAL: BACTERIA, RICKETTSIAE, AND COXIELLA

Values are approximate, representing data obtained under widely varying conditions by many investigators. Data may differ from species to species within the same genus, and even with various cultures of the same species. Temperatures given under thermal death time are assumed to be moist heat, but in some cases this has not been specified in the literature source. Values in parentheses are ranges, probably estimate "c" of the 95% range (cf. Introduction).

Organism	Temperature for Growth ¹ °C	Thermal Death		Organism	Temperature for Growth ¹ °C	Thermal Death	
		°C	min			°C	min
1 Acetobacter roseum	30-35(10-41)	50	5	48 Methanococcus mazel	30-37		
2 Achromobacter ichthyodermis	25(-2 to 30)			49 Micrococcus luteus	25		
3 Actinobacillus lignieresii	37	60	15	50 M. pyogenes var. albus	37	62	10
4 Actinomyces bovis	37	60	10	51 M. pyogenes var. aureus	37(15-40)	60	20
5 A. thermophilus	50(28-65)			52 Micromonospora chacea	30-35	70	5
6 Aerobacter aerogenes	30(to 42-44)	60	30	53 Miyagawanaella lymphogranulomatis	35-37	56	10
7 Agrobacterium tumefaciens	25-28(0-37)			54 Mycobacterium avium	40(30-44)		
8 Alkaligenes faecalis	37			55 M. phlei	37(20-58)	60 ³	60 ⁴
9 Azobacter chroococcum	25-28			56 M. tuberculosis	37(30-42)	65	15
10 Azotomonas indicum	30			57 Mycoplasma dimorpha	30		
11 Bacillus anthracis	35(to 43)	100 ²	10 ²	58 Neisseria gonorrhoeae	37(25-40)	55	<5
12 B. subtilis	30-37(15-55)	100 ²	14	59 N. meningitidis	37(25-42)	50	<5
13 B. thermodiastaticus	65(50-75) ³			60 Nitrobacter winogradskyi	25-28	50	5
14 Bacteroides fragilis	37			61 Nitrosococcus nitrosus	20-25		
15 Bacterium erythrogenes	28-35			62 Nitrosomonas monocella	28		
16 B. phosphoreum	10(5-25)			63 Nocardia asteroides	37	60	60
17 Bartonella bacilliformis	28			64 Noguchia granulosis	30(15-37)	57	10
18 Brucella spp	37(20-40)	60	10	65 Pasteurella multocida	37	60	10
19 Cellfascicula viridis	20			66 P. pestis	25-30(0-45)	55	5
20 Cellulomonas biazotea	20			67 P. tularensis	37(24-39)	56	10
21 Cellvibrio ochraceus	20			68 Pedicoccus cerevisiae	25		
22 Chromobacterium violaceum	25-30			69 Propionibacterium freudenreichii	30		
23 Clostridium botulinum	20-35(18-55)	120 ²	5 ²	70 Proteus vulgaris	37(10-43)	55	60
24 C. perfringens	38	100 ²	20 ²	71 Protaminobacter albolavum	30		
25 C. tetani	37-38(14-50)	105 ²	10 ²	72 Pseudomonas aeruginosa	37(0-42)	62	10
26 Coliforms (various)		60-63	30	73 Rhizobium leguminosarum	25		
27 Corynebacterium diphtheriae	34-36(15-40)	54	10	74 Rickettsia prowazekii	32-35	56	30
28 Coxiella burnetii	37	62	30	75 Rhodopseudomonas palustris	37		
29 Cytophaga hutchinsonii	28-30			76 Rhodospirillum rubrum	30-37		
30 Desulfovibrio desulfuricans	25-30(to 40)			77 Saccharobacterium ovale	34-35(20-37)	54	10
31 Diplococcus pneumoniae	37(18-42)	56	5-7	78 Salmonella typhimurium	37(4-46)	55	24
32 Erwinia carotovora	25-30(4-39)			79 S. typhosa	37(4-46)	60	2
33 Erysipelothrix rhusiopathiae	37(15-44)	55	10	80 Sarcina ventriculi	30(10-45)	65	10
34 Escherichia coli	30-37(10-45)	60	10	81 Serratia marcescens	25-30(to <37)	55	60
35 Flavobacterium aquatile	25			82 Shigella dysenteriae	37(10-40)	60	10
36 Gaffkya tetragena	37(15-39)			83 S. equi	37	60	15
37 Hemophilus influenzae	37(26-43)	50-55	30	84 Spirochaeta daxisensis	42-52	60	30
38 H. pertussis	37	56	60	85 S. plicatilis	20-25		
39 H. suis	37	60	20	86 Sporocytophaga mycoccoides	28-30		
40 Hydrogenomonas pantotropa	28-30			87 Streptococcus pyogenes	37(15-40)	60	15
41 Klebsiella pneumoniae	37(12-43)	55	30	88 Streptomyces thermophilus	40-45(20-<53)	72-74	10
42 Lactobacillus casei	30(10-40)			89 S. griseus	37		
43 L. thermophilus	50-63(30-65)	71	30	90 Thiobacillus thiooxidans	28-30		
44 Leptospira icterohemorrhagiae	25-30(25-37)	56	20	91 Treponema pallidum	37 ⁵	40	60-180
45 Listeria monocytogenes	37	59	10	92 Veillonella parvula	37	55	60
46 Malleomyces mallei	37(15-43)	55	10	93 Vibrio comma	37(14-42)	55-60	2
47 Methanobacterium omelianskii	37-40(to 48)			94 Xanthomonas campestris	28-30(5-38)		

/1/ In this column optimal values are given first, followed in parentheses by a range in which growth occurs but diminishes rapidly as either extreme is approached. /2/ Applies to spores and is an experimental minimum. It is customary to rely only on autoclaving at 121°C for at least 20 minutes to kill these and related spores. /3/ No growth at 50° but growth at 75°. /4/ Survives. /5/ Has never been cultivated in artificial medium.

374. SURVIVAL TIME AND CONDITIONS: BACTERIA PATHOGENIC TO PLANTS

Organism	Thermal Death Point °C	Survival Duration, Various Conditions (W = overwinters) ¹	Organism	Thermal Death Point °C	Survival Duration, Various Conditions (W = overwinters) ¹
1 <i>Agrobacterium tumefaciens</i>	51	24 mo in soil debris ² , hosts ³	21 <i>Pseudomonas pisi</i>	50	W in or on seeds
2 <i>Corynebacterium agropyri</i>	50	12 mo in dried exudate	22 <i>P. savastanoi</i>	43-46	W in insect body, hosts ³
3 <i>C. fascians</i>	50-57	W in or on seeds	23 <i>P. solanacearum</i>	52	>2 yr in soil
4 <i>C. flaccumfaciens</i>	57.5-60	2.5 yr in seed	24 <i>P. syringae</i>	51	W in or on seeds ⁵ , hosts ³
5 <i>C. insidiosum</i>	51-52	W in soil debris, hosts ³	25 <i>P. tabaci</i>	49-51	W in soil debris
6 <i>C. michiganense</i>	53	W in or on seeds, soil	26 <i>P. viridiflava</i>	48-50	W in or on seeds
7 <i>C. sepedonicum</i>		W in soil ^{4, 5, 6}	27 <i>Xanthomonas begoniae</i>	49-50	W in hosts ³
8 <i>Erwinia amylovora</i>	45.1-49.5	W ⁷ in soil, insect body, hosts ³	28 <i>X. campestris</i>	51	W in or on seeds ^{3, 5}
9 <i>E. atroseptica</i>	48-51	W in soil, insect body ⁴	29 <i>X. carotae</i>	49	W in or on seeds ^{3, 5}
10 <i>E. carotovora</i>	48-51	W in soil, insect body ⁴	30 <i>X. citri</i>		W in hosts ³
11 <i>E. tracheiphila</i>	43	W in insect body	31 <i>X. hyacinthi</i>	47.5-49	W in tubers, corms
12 <i>Pseudomonas caryophylli</i>		W in soil	32 <i>X. juglandis</i>	53-55	W in hosts ³
13 <i>P. coronafaciens</i>	48	W in or on seeds	33 <i>X. malvacearum</i>	50-51	W in or on seed
14 <i>P. gladioli</i>	47	W in tubers, corms	34 <i>X. papavericola</i>	52	W in soil debris, hosts ³
15 <i>P. glycinea</i>	48-49	W in or on seeds	35 <i>X. phaseoli</i>	48-50	W in or on seeds, soil ⁶
16 <i>P. lachrymans</i>	49-50	24 mo in or on seeds	36 <i>X. pruni</i>	51-52	W in hosts ³
17 <i>P. maculicola</i>	46	W in or on seeds	37 <i>X. rubrilineans</i>	51-52	W in hosts ^{3, 4}
18 <i>P. marginata</i>	53	W in tubers, corms	38 <i>X. stewartii</i>	53	W in insect body, seeds
19 <i>P. mori</i>	51.5	W in hosts ³	39 <i>X. translucens hordei</i>	50	W in or on seeds
20 <i>P. phaseolicola</i>		W in or on seeds	40 <i>X. vesicatoria</i>	56	W in seeds, soil ⁸

/1/ Organism in specified condition survives the winter. /2/ W on plant roots. /3/ In perennial or biennial hosts. /4/ W also in tubers, corms, bulbs, etc. /5/ W also in soil debris. /6/ W also in dried exudate. /7/ In beeswax 1.8 mo. /8/ Associated with wheat roots.

375. EFFECTS OF TEMPERATURE ON GROWTH AND SURVIVAL: FUNGI

Part I: PLANT PATHOGENS		
Species	Temp for Growth ¹ °C	Method of Overwintering
Phycomycetes		
1 <i>Albugo candida</i>	10(1-20)S	Soil; crucifers
2 <i>Peronospora effusa</i>	8-10(3-30)S	Soil; spinach
3 <i>P. parasitica</i>	8-12(to 29)S	
4 <i>P. tabacina</i>	15-23(1-29)S	Plant debris
5 <i>Physoderma zeae-maydis</i>	28-29(23-30)S	Soil; plant debris
6 <i>Phytophthora infestans</i>	20(7-30)C	Soil; tubers
7 <i>Plasmiodiophora brassicae</i>	25-27(10-30)S	Soil
8 <i>Plasmodiophora viticola</i>	25-28(8-35)S	Buds; leaves
9 <i>Pseudoperonospora cubensis</i>	20	
10 <i>Phythium debaryanum</i>	27-30(5-35)C	Soil
11 <i>Rhizopus nigricans</i>	25-30(7-35)C	Soil
12 <i>Spongospora subterranea</i>	20-23(12-35)	Soil
Ascomycetes		
13 <i>Ceratostomella ulmi</i>	22-27(5-40)C	
14 <i>Claviceps purpurea</i>	22-26C	Soil; among seeds
15 <i>Dibotryon morbosum</i>	37(?)	Twig knots
16 <i>Diplocarpon rosae</i>	16-21	Plant debris
17 <i>Endothia parasitica</i>	25-30(4-40)C	Cankers
18 <i>Erysiphe graminis</i>	15-20(5-29)S	Plant debris
19 <i>Gibberella zeae</i>	20-30(3-37)C	Plant debris; soil
20 <i>Glomerella gossypii</i>	25(18-33)	Soil; seed coat
21 <i>Monilinia fruticola</i>	24(0-32)C	Mummy
22 <i>Physalospora malorum</i>	20(10-30)	Cankers; plant debris
23 <i>Podosphaera leucotricha</i>	19-20(10-28)S	Leaf and flower buds
24 <i>Sphaerotheca humuli</i>	37(?)	Plant debris
25 <i>Taphrina deformans</i>	20(10-30)C	Plant debris; bark
26 <i>Venturia inaequalis</i>	20(4-32)C	Plant debris
Basidiomycetes		
27 <i>Armillaria mellea</i>	25(15-30)C	Soil
28 <i>Cronartium ribicola</i>	12-18(5-25)S	Pine; Ribes
29 <i>Fomes ignarius</i>	30-32(to 42)C	Wood
30 <i>Gymnosporangium juniperi-virginianae</i>	20-25(6-32)S	Redcedar
31 <i>Puccinia antirrhini</i>	10(5-30)S	Plant debris
32 <i>P. coronata</i>	17-22(2-35)S	Plant debris
33 <i>P. graminis</i>	12-20(2-35)S	Wheat
34 <i>P. tritici</i>	16-20(2-31)S	Wheat
35 <i>Tilletia caries</i>	15-20(4-29)S	Soil; seed coat
36	(1-25)C	Soil; seed coat
37 <i>Uromyces cariophyllinus</i>	14(4-29)S	Plant debris
38 <i>Ustilago avenae</i>	20-28(4-35)S	Soil; within seed
39	18-26(6-34)C	Soil; within seed
40 <i>U. tritici</i>	20-25(5-35)S	Within seed
41	20-25(8-34)C	Within seed
42 <i>U. zeae</i>	25-30(8-40)S	Soil; plant debris
Fungi imperfecti		
43 <i>Alternaria solani</i>	26-28(1.5-45)C	Soil; plant debris
44 <i>Botrytis cinerea</i>	20-25(0-30)C	Apple fruit
45 <i>Cercospora beticola</i>	25-30(6-34)C	Plant debris
46 <i>Cladosporium carpophilum</i>	19-28(2-33)C	Cankers

(continued on next page)

/1/ Desirable temperature for growth, with range (where known) in parentheses, followed by a symbol for the type of growth: C = in culture; S = spore germination.

Part II: ANIMAL PATHOGENS AND RELATED SAPROPHYTES

Data are for artificial culture, under humidity conditions favoring growth.

Species	Temp for Growth ¹ °C	Thermal Death °C	min
1 <i>Absidia corymbifera</i>	28-40(20-46)[37]		
2 <i>Achorion castellani</i>	[20]		
3 <i>Actinobacillus lignieresii</i>	37(min 20)[37]	62	10
4 <i>Allescheria boydii</i>	25-30(15-45)[30]	56	80
5 <i>Aspergillus bronchialis</i>	[34]		
6 <i>A. fumigatus</i>	25-45(max >50)[40]		
7 <i>A. nidulans</i>	25-37[36-38]		
8 <i>A. niger</i>	25-37(max <60)[37]		
9 <i>Blastomyces brasiliensis</i>	25-30[25-30]	60	60
10 <i>Yeast phase</i>	37	60	60
11 <i>B. dermatitidis</i>	25-33(8-40)[31]	56	60
12 <i>Yeast phase</i>	35-37[35]	56	60
13 <i>Candida albicans</i>	24-40(<20->40)[30-37]	60	10
14 <i>C. guilliermondii</i>	25-37[30-37]		
15 <i>C. krusei</i>	25-37[30-37]		
16 <i>C. tropicalis</i>	25-37[30-37]	60	10
17 <i>Castellania hashimotoi</i>	[22-25]		
18 <i>Cephalosporium granulomatis</i>	Room to 37	53	5
19 <i>C. ricci</i>	Room [25-30]		
20 <i>Cladosporium gougerotii</i>	25-37		
21 <i>C. sphaerospermum</i>	Room (min <18)		
22 <i>C. trichoides</i>	Room to 30[30]		
23 <i>C. mansoni</i>	25-35[30-32]		
24 <i>Coccidioides immitis</i>	25-37(max <42)[30-37]	60	4
25 <i>Corynebacterium acnes</i>	37(30-<45)[37]	60	10
26 <i>C. tenuis</i>	30-37[about 37]		
27 <i>Cryptococcus neoformans</i>	25-37(<17-40)[25-30]	50	10
28 <i>Debaryomyces hansenii</i>	30-35(3-37)		
29 <i>D. laedegardii</i> (D. hildegaardii)	25(5-37)		
30 <i>Endomyces pulmonalis</i>	33-37(>5-<41)		
31 <i>Epidermophyton floccosum</i>	25-30(min <18)[27±]	50	10
32 <i>Geotrichum candidum</i>	25-37	56	60
33 <i>G. issawi</i>	22-25		
34 <i>Hansenula anomala</i>	(0.5-38)		
35 <i>Histoplasma capsulatum</i>	22-30(10-40)[25-30]	55	15
36 <i>Yeast phase</i>	34-37(<34->43)[37±]	55	30
37 <i>H. farciminosum</i>	25-37(15-40)[37]		
38 <i>Hormodendrum compactum</i>	25-37[37]	100	15
39 <i>H. dermatitidis</i>	Room to 30		
	(max <43)[20-30]		
40 <i>H. pedrosoi</i>	25-37[37]	100	15
41 <i>Madurella grisea</i>	Room to 37[30]		
42 <i>Microsporium audouinii</i>	25-30(max 38)[25-30]	60	60
43 <i>M. canis</i>	25-32(max 40)[30-32]	70	10
44 <i>M. gypseum</i>	25-30(max 38)[25-30]	60	60
45 <i>Nocardia asteroides</i>	25-37[37]	70	5
46 <i>N. brasiliensis</i>	Room to 37	60	60
47 <i>N. caprae</i>	Room to 37[33-37]		
48 <i>N. farcinica</i>	30-40(min >24)[37]	70	10
49 <i>N. intracellularis</i>	37(37.5)	60	10

(continued on next page)

/1/ Desirable temperature for growth, with range (where known) in parentheses, and optimum growth temperature in brackets.

375. EFFECTS OF TEMPERATURE ON GROWTH AND SURVIVAL: FUNGI (Concluded)

Part I: PLANT PATHOGENS (Concluded)			Part II: ANIMAL PATHOGENS AND RELATED SAPROPHYTES (Concluded)		
Species	Temp for Growth ¹ °C	Method of Overwintering	Species	Temp for Growth ¹ °C	Thermal Death °C min
Fungi imperfecti (concluded)			50 N. madurae	Room to 37(<20-40)[37]	60 5
47 Colletotrichum lagenarium	22-24(6-35)C	Soil	51 N. paraguayensis	Room to 37	60 60
48 C. lindemuthianum	20-23(4-35)C	Within seed	52 Phialophora jeanselmei	Room to 37[30]	
49 Diplodia zeae	30(10-35)C	Soil; within seed	53 P. verrucosa	25-37[37]	100 15
50 Fusarium cubense var. oxysporum	20-30(5-37.5)C	Soil	54 Pityosporum ovale	30-37(min <22)[37]	60 30
51 F. lycopersici	24-30(5-38)C	Soil	55 Rhizopus arrhizus	(6-43)[32.5-35.5]	
52 F. vasinfectum	28-30(10-38)C	Soil	56 R. equinus	(min >5)[37-39]	100 20
53 Helminthosporium gramineum	15-20 C	Seed coat	57 R. oryzae	(7.5-45.5)[31-34]	
54 Phomopsis citri	24-28(9-34)C	Plant debris	58 Schizophyllum commune	(<16->40)[30a]	
55 Phyllosticta solitaria	25-30(5-35)C	Soil debris	59 Scopulariopsis brevicaulis	Room (<6-37)[20-25]	
56 Phymatotrichum omnivorum	29(18-36)C	Soil; roots	60 Sporotrichum schenckii	Room to 37[30-37]	59 5
57 Septoria apii-graveolentis	22-24(14-25)C	Plant debris; seed coat	61 Trichophyton concentricum	25-37[37a]	
58 Thielaviopsis basicola	17-33	Soil	62 T. ferrugineum	25	60 10
59 Verticillium albo-atrum	21-26(8-31)C	Soil	63 T. megyni	25	55 10
Mycelia sterilia			64 T. mentagrophytes	25-30(8-40)[30]	60-70 10
60 Rhizoctonia solani	31(8-40)C	Soil	65 T. schoenleini	25-37(min <15)[33]	60 10
61 Sclerotium cepivorum	20-24(5-29)C	Soil	66 T. tonsurans	25-37[30]	
			67 T. violaceum	25-37[25-30]	
			68 Trichosporon beigeli	Room to 37 (max <43)[30-37]	

/1/ Desirable temperature for growth, with range (where known) in parentheses, followed by a symbol for the type of growth: C = in culture; S = spore germination.

/1/ Desirable temperature for growth, with range (where known) in parentheses, and optimum growth temperature in brackets.

376. EFFECTS OF TEMPERATURE: PLANT PATHOGENIC FUNGI

Values not in parentheses are "optimum" values in °C; values in parentheses are minimum-maximum values in °C. The following symbols, in brackets, identify, where known, the part or stage studied: ae = aeciospores; as = ascospores; b = basidiospores; c = conidia; m = mycelium; o = oospores; p = pycnidia, pycnospores; s = spores (not specified); sa = sporangia; sc = sclerotia; t = teliospores; u = uredospores; z = zoospores.

Fungus	Germination	Development in Culture	Fructification and/or Sporulation	Infection	Disease Development	Infection and Disease Development	Thermal Death Point ¹
1 Actinomyces scabies ²	16-37	25-32(8-40)			14-22(11-31)		
2 Albugo candida ²	14-20(0-25)[c]	10-13(0-25)					
3 Alternaria brassicae	33-35(1-46)	25-27(2-36)				25-31(2-36)	55
4 A. citri ²		25				25-30	
5 A. solani ²	26-28(1-45)	26-28(1-45)				24-25	
6 Aphanomyces euteiches		15-34(9-37)	(9-35)			15-30(10-30)	65[m]
7 Armillaria mellea ²		25(15-30)	18-22				99 ³ ; 62 ⁴ [s]
8 Ascochyta pisi	20(10-35)	20-28(0-35)					
9 Aspergillus niger ²		30-39(7-46)					
10 Basidiosporium gallarum ²	20-35(9-35)	25-35(10-40)					
11 Botryosphaeria ribis ²		28-30(10-35)			18-28(13-33)		
12 Botrytis allii ²	19-27(3-27)	20-25(3-33)	4-25(4-25+)			15-20(2-40)	
13 B. cinerea ⁵	17-25(1-35)	15-25(0-35)	16-30(4-37)			7-25(0-35)	55
14 Calonectria graminicola ²		20-22(0-33)		0-10(to 20)			
15 Cephalothecium rosae ²	19-33(9-35)	20-25(5-35)			25(0 to)		
16 Ceratostomella fimbriata		23-29(9-36)				23-27(9-36)	
17 C. ips		27-29(6-35)	27-31(6-35)				52
18 C. ulmi		19-28(5-40)				51-57[s]	
19 Cercospora beticola	26-33(2-35)	24-30(5-40)	24-32(17-34)	21-32			95 ³ ; 46 ⁴
20 Cercospora herpetchoides		20-23(-5 to 30)			5-9		
21 Choanephoridae cucurbitae	15-20	30(9-35)	20(10-25)				
22 Cladosporium carpophilum		19-28(2-33)					
23 C. cucumerinum		20-21(0-32)					
24 C. fulvum ²	18-26(0-33)	16-26(0-34)	20-26(2-35)	20(to 35)		21-25(7-29)	70 ³
25 C. malorum		25			20-25		
26 Claviceps purpurea	18-22[sc]	22-30	17-21				
27 Coccomyces hiemalis		20-24(4-28)	12-16(4-28)	8-28			
28 Colletotrichum circinans	20-26(4-32)	26(2-32)				20-30	
29 C. lagenarium	22-32(4 to)	22-23(6-35)		20-28			
30 C. lindemuthianum ²	20-32(0-42)	18-30(0-42)	12-15(4-28)			25(6-33)	
31 Coniothyrium wernsdorffiae	16-17(0-27)	20-21(-1 to 26)				10-16(to 27)	
32 Corticium vagum ⁵	20-32(8-36)[sc]	20-33(0-44)	18-21			9-30(1-36)	60[sc]
33 Cronartium ribicola	12(5-19)[ae]; 10-18(0-21)[b]; 12-18(0-21)[t]; 14(8-25)[u]						
34 Dasyscypha willkommii	15-27(<13-31)	18-23					
35 Deuterophoma tracheiphila	18-20(15 to)	(10-28)	12-28[c]; 12-24[p]				
36 Diplodia zeae	30[p]	24-32(10-36)	25-30[p]			21-32(15 to)	
37 Endothia parasitica ²	21[as]; 15-32	18-30(4-40)	16-27(2-38)[as]; 30[p]				
38 Erysiphe graminis	18[as]; 12-21(<5-29)[c]	10(0-25)		20			
39 E. polygoni ⁵			15-24(<8-30)[c]	15-25 or 24-32 ³ [p]			
40 Fomes applanatus ²		27-30(15-35)					65[m]
41 Fusarium conglutinans		20-30(5-35)				16-28(12-34)	
42 F. lini ²	12-30(7-35)	18-30(5-37)				15-21(12-38)	
43 F. lycopersici ²		24-30(5-38)				27-29(21-33)	
44 F. oxysporum ⁵		15-32(4-40)				14-32(>5 to >38)	57

/1/ Usually at 10 min exposure. /2/ Fungus exhibits variability among different strains or in different hosts. /3/ Dry state. /4/ Wet state.

/5/ Fungus exhibits extreme variability among different strains or in different hosts.

376. EFFECTS OF TEMPERATURE: PLANT PATHOGENIC FUNGI (Continued)

Values not in parentheses are "optimum" values in °C; values in parentheses are minimum-maximum values in °C. The following symbols, in brackets, identify, where known, the part or stage studied: ae = aeciospores; as = ascospores; b = basidiospores; c = conidia; m = mycelium; o = oospores; p = pycnidia, pycnosporangia; s = spores (not specified); sa = sporangia; sc = sclerotia; t = teliospores; u = uredospores; z = zoospores.

Fungus	Germination	Development in Culture	Fructification and/or Sporulation	Infection	Disease Development	Infection and Disease Development	Thermal Death Point ¹
45 <i>Fusarium solani</i> martii ²	13-25(5-37)	18-34(5-39)			21-34		
46 <i>F. vasinfectum</i> ²		25-35(5-40)	27-38			17-33(10-35)	
47 <i>Gibberella zeae</i> ⁵	30(5-32)[as]; 24-28(4-32)[c]	20-30(3-37)	20-27(to 37)[as]; 20-28(4-34)[c]			24-28(8-39) ⁶	>65[as]
48 <i>Gloeosporium venetum</i>	22-26(11-32)	20-26(11-31)					
49 <i>Glomerella gossypii</i>		25-29(10-38)			<24 38		>95 ³ ; 51 ⁴ [c]
50 <i>G. rufomaculans</i>	19-36(3-26)	33-38(9-38)					
51 <i>Guignardia bidwellii</i>		20-30	20-25(9-35)[p]				>60[s]
52 <i>Gymnosporangium juniperi-virginianae</i> ²	24(6-32)[ae]; 16(8-28)[b]; 22-25(4-32)[t]					16-19(10 to)	
53 <i>Helminthosporium turcicum</i>		28-30(7-35)	20-28(11-33)		<30		
54 <i>Hypochnus centrifugus</i> ²		28-35(8-41)	27-35			20-35(2 to)	
55 <i>Lentinus lepideus</i>		27-28(<9-40)			<24		>105 ³ ; >60 ⁴ [m]
56 <i>Macrophoma phaseoli</i> ²		31(8-42)				20-40(12 to)	55
57 <i>Merulius lacrymans</i> ²	22-25	20-26(4-32)					50-55[m]
58 <i>Monilinia fructicola</i>		24-27(0-32)					
59 <i>Mycogone perniciosa</i>		21-28(8-32)				15-21	>42
60 <i>Mycosphaerella rubi</i>	23(2-32)[as]; 23(2-32)[p]	20-23(2-32)					
61 <i>Nectria cinnabarina</i>	17-20(5-30)[as]; 20-25(>0-35)[c]	21(3-33)					
62 <i>Neofabraea malicorticis</i>	15-25(0-30)	20(0 to <30)			20(0 to)		
63 <i>Nigrospora oryzae</i>	30(10-47)	30(10-35)					>67 ³ , 56 ⁴ [s]
64 <i>Ophiobolus graminis</i> ²		19-30(3-35)				12-24(9-32)	
65 <i>O. miyabeanus</i> ²	25[as]; 25-30 (2-41)[c]	24-32(5-40)	25-28[as]; 20-30 (5-38)[c]			25-30(16-40)	
66 <i>O. sativus</i> ²	22-32(6-39)[c]	25-33(1-37)	15-28(10-30)[c]			22-30(8-35)	54
67 <i>Penicillium expansum</i>		25-27(0-30)			25(0 to)		
68 <i>Peronosplasmopara cubensis</i> ²	15-22(1-32)[c]		15-22(7-30)			16-22(10-30)	
69 <i>P. humuli</i>	17-20[c]; 20-22 [o]		15-20(0-28)[c]; 17-20[z]	18-22(4-30)			
70 <i>Peronospora parasitica</i>	8-12(to <29) [c]	8-12(to 29)		3-8			
71 <i>P. tabacina</i>	15-23(1-29)	to 20	21-22(to 26)	11-25(5-30)			
72 <i>Phomopsis citri</i>	20-27(16-33)	24-38(4 to <40)	20(10 to <28)	20-25(15-30)			
73 <i>Phyllosticta solitaria</i>	25-30(5-39)	25-30(5-35)	19-30				
74 <i>Phymatotrichum omnivorum</i>		30	21-32(18-36)				46-51
75 <i>Physoderma zeae-maydis</i>	28-29(23-30)						>80
76 <i>Phytophthora cactorum</i>	25-27[c]	20-36(5-38)				20-25(9-30)	
77 <i>P. cinnamomi</i> ²		20-30(5-33)	21-29(to 35)				
78 <i>P. citrophthora</i> ²	28-30; 15-18	25-38(5-37)		20-21			
79 <i>P. infestans</i> ⁵	4-20(1-30)	15-25(2-35)	16-23			10-13 ⁷	45[m]; 25[s]
80 <i>P. parasitica</i> ⁵	25-27	20-35(5-44)				21-25	
81 <i>Piricularia oryzae</i>	25-30(16-35)[c]	25-30(8-40)	18-30(10-35)			24-28(to 34)	51[c]; 52-55[m]
82 <i>Plasmodiophora brassicae</i>	25-30(6-27)					25(9-30)	
83 <i>Plasmopara viticola</i> ²	25-35(5-35) ⁸ [c]; 23-35(11-33)[o]		18-22(8-30)			18-25(9 to <30)	
84 <i>Polystictus versicolor</i> ²		25-32 ⁹			27-32		>70[m]
85 <i>Pseudopeziza ribis</i>	12[as]; 20[c]	20(<4 to 32)	(1-32)[as]; 8-24 (<4 to <32)[c]				
86 <i>Puccinia coronata</i> ²	12-22(0-35)				12-17(7-30)		
87 <i>P. glumarum</i> ²	10-20(2-29)[u]		10-16(0-20)[u]			10-15	
88 <i>P. graminis</i> ⁵	5-20(<5 to >30) [ae]; 15-20[b]; 12-20(5-30) [t]; 5-25(2-35)[u]		12-18[p]			12-21(to 26); 20-25 (10-30)[u]	
89 <i>P. helianthi</i>	18(6-28)[t]; 18(<6 to >28)[u]					(10 to)	
90 <i>P. sorghi</i>	15-18(4-32)[u]					18-20(<8 to 32)[u]	
91 <i>P. tritici</i> ²	10-26(2-32)[u]			20(2-31)[u]	15-22[u]		
92 <i>Pyrenophora graminea</i>		18-30(3-35)				10-18(to 24)	52[c]; 55[m]
93 <i>P. teres</i>	20[as]; 20-25 [c]	23-30(3-33)	5-30[c]; 10-30 [p]	15-35			45[c]; 55[m]
94 <i>Pythiacystis citrophthora</i>		25-27(9-32)			18-28(6-32)		46[s]
95 <i>Pythium debaryanum</i> ⁵		24-33(5-40)				30-35 ¹⁰	
96 <i>P. ultimum</i>		25-35(2-42)				12-21(2-35)	
97 <i>Rhizopus nigricans</i> ²	19-41(2-41)	20-36(2-40)	16-30(7-32)			6-28(0-36)	55[s]
98 <i>Sclerospora graminicola</i>	18-30(5-35)[c]; 20-34(10-38) [o]; 14-18[sa]; 25-27(8-30)[z]		17-27(5-35)[sa]	17-20(11-34)[o]			40[c]; 118 ³ , 53 ⁴ [o]
99 <i>Sclerotinia americana</i>	23[c]	24(27(3-33)					
100 <i>S. fructigena</i>	21-25(10 to) [c]	18-25(0-33)	28-33(5-30)			(5 to <35)	52
101 <i>S. libertiana</i>	(3-31); (to 30)[as]	22-25(0-33)	20-25		18-23(0 to >33)		60[sc]
102 <i>S. sclerotiorum</i> ²	25(3-30)[as]	22-25(0-33)				17-24(0-28)	50 ⁴ [sc]
103 <i>Septoria apii</i>		16-27(10-27)	16-25				

/1/ Usually at 10 min exposure. /2/ Fungus exhibits variability among different strains or in different hosts. /3/ Dry state. /4/ Wet state. /5/ Fungus exhibits extreme variability among different strains or in different hosts. /6/ Value also reported as 8-16 (to 28). /7/ Also 18-32(3-37). /8/ Also 10-16(2-27). /9/ Also 15(0-40). /10/ Also 15-30, or 5-8.

376. EFFECTS OF TEMPERATURE: PLANT PATHOGENIC FUNGI (Concluded)

Values not in parentheses are "optimum" values in °C; values in parentheses are minimum-maximum values in °C. The following symbols, in brackets, identify, where known, the part or stage studied: ae = aeciospores; as = ascospores; b = basidiospores; c = conidia; m = mycelium; o = oospores; p = pycnidia, pycnospores; s = spores (not specified); sa = sporangia; sc = sclerotia; t = teliospores; u = uredospores; z = zoospores.

Fungus	Germination	Development in Culture	Fructification and/or Sporulation	Infection	Disease Development	Infection and Disease Development	Thermal Death Point ¹
104 Septoria lycopersici		25(2-34)	25(15-27)				53[s]
105 S. tritici	2-32	20-24(3-32)					
106 Synchytrium endobioticum	12-20(5-30)			16-18(0-30)			85 ⁴ [sa]
107 Taphrina deformans		<20-20(10-30)				13-17(10-21)	46[m]
108 Thielaviopsis basicola		23-32(7-37)				17-23(15-32)	
109 Tilletia laevis	16-20(4-36)	20		5-10(to 25)			
110 T. tritici	15-20(0-36)	20(>1 to <25)		6-12(4-22)			
111 Trametes pini		20-25(10-40)					65-70[m]
112 Urocystis cepulae	15(4-28)[m]; 15-20(9 to >32)[s]	>18(>9 to 28)				10-25(10-28)	
113 Uromyces trifolii	15-20(6-30)[ae] 17(7 to <30) [t]; 9-25(<3 to >33)[u]						
114 Ustilago avenae	15-30(4-35)[u]; 15-28(0-35)[t]	18-26(6-34)		18-22(7-32)			45-53
115 U. hordei ²	10-30(0-35)	16-26(<-1 to <35)					43-48
116 U. nuda ²	20-29(0-34)	20-25(<10-35)					>42[s]
117 U. tritici ²	22-30(0-35)	24-30(6 to >35)	19-24	23-25(10-30)			45-48
118 U. zeae	25-34(5-40)[t]; 20-26 (to 40)[u]	18-26(10-34)		27-35			106 ³ ; 52 ⁴ [s]
119 Venturia inaequalis	13-22(0-35)[as]; 14-25(2-31)[c]	20(<4 to <32)				19(6-24)	
120 Verticillium albo-atrum		16-31(4-37)	23(8-31)		21-25		

/1/ Usually at 10 min exposure. /2/ Fungus exhibits variability among different strains or in different hosts. /3/ Dry state. /4/ Wet state.

377. TEMPERATURE CHARACTERISTICS: PLANTS

Part I: TEMPERATURE TOLERANCE EXTREMES: ALGAE

Most values in this table are based on observations of algae growing under natural conditions where it is difficult to determine the true temperature of the habitat. Moreover, light absorption may raise the temperature of an algal mass above that of its surroundings. Values, therefore, should be interpreted with caution. * = temperature for maximum growth rate. Where values are given for general groups it is implied that these hold for some but not necessarily all species in that group.

Species	Maximum for Habitat ¹	Maximum Tolerated	Minimum Tolerated	Species	Maximum for Habitat ¹	Maximum Tolerated	Minimum Tolerated
Temperature, °C				Temperature, °C			
1 Cyanophyta (blue-green)		85		31 Cyanophyta (blue-green) (concluded)			
2 40 non-thermal spp		40		32 Scytonema mirabile			Below -17
3 Anabaena sp	40			33 Synechocystis thermalis	62.2		
4 A. variabilis	35*			34 Synechococcus eximius	79*	84	70
5 Anacystis nidulans	41*			35 S. vulcanus	70*	85	46
6 A. thermalis	42*			36 S. vulcanus bacillarioides	64*	70	57
7 Chroococcus sp	57			37 Chlorophyceae (green)		50	-18 to -20 ⁴
8 C. minutis fuscus	46			38 Ankistrodesmus falcatus		35	Below -17
9 C. yellowstonensis	41			39 Chaetomorpha linum		10	-2 to -7
10 Cylindrospermum stagnate	44.1			40 Chlamydomonas nivalis		72-74	-36
11 Gleocapsa stegophalia	38			41 Chlamydothrix thermalis		35	Below -7
12 Lyngbya sp	65			42 Cladophora hamosa		35	Below -7
13 L. cutialis			Below -17	43 C. laetevirens		30-35	-2 to -7
14 Mastigocladus laminosus	65		-19	44 C. proliferans			-16.8 to -20
15 Microcystis elabens			Below -17	45 Cosmarium conspersum			Below -17
16 Nostoc kuhlmani			Below -17	46 Desmidium quadratum			Below -17
17 N. muscorum	32.5*			47 Enteromorpha intestinalis			-18 to -20 ⁴
18 N. sphaericum	30			48 Euastrum sublobatum			Below -17
19 Oscillatoria amphibia	50			49 Protococcus botryoides	80		
20 O. filiformis	85.2 ²	85.2 ³	59	50 Ulothrix sp		17	
21 O. formosa	50			51 Chrysophyta			
22 O. geminata	45			52 Bacillariophyceae (diatoms)		50.7	-11
23 O. okeni	44			53 Nitzschia putrida		30	-11
24 O. proboscidea	47			54 Chrysophyceae (golden brown)		40.2	
25 O. tennis tergestina	44			55 Xanthophyceae (yellow-green)		32.5	
26 Phormidium bijahensis	60-62*	85.2 ³	38	56 Phaeophyta (brown)		30	-18 to -20 ⁴
27 P. geysericola	75*	85	58	57 Fucus vesiculosus		30	-18 to -20 ⁴
28 P. laminosum	75*	85	58	58 Rhodophyta (red)			-18 to -20 ⁴
29 P. tenue	47.2			59 Bangia fuscopurpurea			-18 to -20 ⁴
30 Rivularia globiceps	26.4			60 Porphyra hiemalis			-18 to -20 ⁴

/1/ Highest temperature reported for natural habitats. /2/ Optimum temperature, 75°C. /3/ Highest recorded temperature for algal growth. /4/ Based on observations of algae in polar seas; not certain that algae were actually growing.

377. TEMPERATURE CHARACTERISTICS: PLANTS (Continued)

Part II: COLD TOLERANCE: MARINE ALGAE

After 10 hr controlled exposure recorded in western Sweden. + = living; - = dead.

Species	Temperature, °C						
	-2.9	-4.0	-5.7	-7.8	-10.7	-16.8	-18 to -20
Red Algae							
1 <i>Trailella intricata</i>	-	-	-	-	-	-	-
2 <i>Laurencia pinnatifida</i>	+	-	-	-	-	-	-
3 <i>Delesseria sanguinea</i>	+	-	-	-	-	-	-
4 <i>D. sinuosa</i>	+	+	-	-	-	-	-
5 <i>Ceramium rubrum</i>	+	+	-	-	-	-	-
6 <i>Chondrus crispus</i>	+	+	-	-	+	-	-
7 <i>Nemalion multifidum</i> ¹	+	+	-	-	+	+	+
8 <i>Bangia fuscopurpurea</i>	+	+	-	-	+	+	+
9 <i>Porphyra hiemalis</i>	+	+	-	-	+	+	+
Brown Algae							
10 <i>Laminaria saccharina</i> ²	+	+	-	-	-	-	-
11 <i>L. digitata</i> ³	+	+	-	-	-	-	-
12 <i>L. saccharina</i> ⁴	+	+	-	-	-	-	-
13 <i>Pylaiella littoralis</i>	+	+	-	-	-	-	-
14 <i>Fucus vesiculosus</i>	+	+	-	-	-	-	-
15 <i>F. serratus</i>	+	+	-	-	-	-	-
16 <i>Ascophyllum nodosum</i>	+	+	-	-	-	-	-
Green Algae							
17 <i>Cladophora rupestris</i>	+	+	-	-	-	-	-
18 <i>Enteromorpha intestinalis</i>	+	+	-	-	-	-	-

/1/ Prostrate protonematal stage in winter. /2/ One year old.
 /3/ Young thallus. /4/ Old thallus; plant several years old.

Part III: TEMPERATURE TOLERANCES: MARINE ALGAE

After 12 hr controlled exposure recorded at Naples. + = living; - = dead; O = not examined.

Algae	Temperature, °C						
	-7	-2	1 to 2	27	30	35	42
Intertidal Zone							
1 <i>Bangia fuscopurpurea</i>	+	+	+	+	+	+	-
2 <i>Cladophora bertolinii</i>	+	+	+	+	+	+	-
3 <i>C. hamosa</i>	+	+	+	+	+	+	-
4 <i>C. laetevirens</i>	+	+	+	+	+	+	-
5 <i>C. spinulosa</i>	O	+	+	+	+	+	-
6 <i>Polysiphonia pulvinata</i>	+	+	+	+	+	+	-
7 <i>Porphyra leucosticta</i>	+	+	+	+	+	+	-
Low Water Level							
8 <i>Anthamion cruciatum</i>	-	+	+	+	+	+	-
9 <i>Callithamnion granulatum</i>	-	O	O	+	+	+	-
10 <i>Ceramium bernerii</i>	-	-	-	+	+	+	-
11 <i>Chaetomorpha linum</i>	-	+	+	+	+	+	-
Depth							
12 <i>Acrosorium uncinatum</i>	-	+	+	+	+	+	-
13 <i>Callithamnion scopulorum</i>	-	+	+	+	+	+	-
14 <i>Ceramium strictum</i>	-	+	+	+	+	+	-
15 <i>Cladophora prolifera</i>	-	+	+	+	+	+	-
16 <i>C. ramellosa</i>	-	O	O	+	+	+	-
17 <i>C. utriculosa</i>	-	+	+	+	+	+	-
18 <i>Griffithsia furcellata</i>	-	-	-	+	+	+	-
19 <i>G. schousboei</i>	O	O	O	+	+	+	-
20 <i>G. setacea</i>	-	-	-	+	+	+	-
21 <i>Nitophyllum punctatum</i>	-	+	+	+	+	+	-
22 <i>Pleonosporium borrieri</i>	-	+	+	+	+	+	-
23 <i>Plocamium coccineum</i>	-	+	+	+	+	+	-
24 <i>Taonia atomaria</i>	-	O	O	+	+	+	-

Part IV: WORLD-WIDE DISTRIBUTION: THERMAL ALGAE

Temp °C	Cyano-phyceae	Chloro-phyceae	Conju-gatae	Rhodo-phyceae
Number of Species				
1 17-30	41	9	4	1
2 30-35	38	7	2	0
3 35-40	62	8	6	0
4 40-45	37	5	1	1
5 45-50	35	4	0	0
6 50-60	37	3	2	0
7 60-75	10	0	0	0

Part V: MAXIMUM TEMPERATURE TOLERANCE: LICHENS

Values are for air-dry tissue. Those in parentheses are for water-soaked tissue. After treatment of air-dry tissue for 30 min, a 50% decrease in respiration was observed.

Lichen	Temp °C	Lichen	Temp °C
Hygrophilic		Xerophytic	
1 <i>Alectoria implexa</i>	72-73	7 <i>Cladonia foliacea convoluta</i>	92-96
2 <i>A. ochroleuca</i>	72	8 <i>C. pocillum</i> , <i>C. pyxidata</i>	101
3 <i>A. sarmentosa</i>	70-74	9 <i>C. rangiformis pungens</i>	99(46.5)
4 <i>Lobaria pulmonaria</i>	73(36.5)	10 <i>Umbilicaria cylindrica</i>	95
5 <i>Usnea dasypoga</i>	71-74(<35)	11 <i>U. hirsuta</i>	100
6 <i>U. florida</i>	70	12 <i>U. pustulata</i>	98(45.5)
		13 <i>U. vellea</i>	98-100(44)

Part VI: TOLERANCE TO EXTREMES OF HEAT AND COLD: MOSSES

Moss	Temp °C	Moss	Temp °C	Moss	Temp °C
Maximum Temperature¹		Maximum Temperature¹ (continued)		Maximum Temperature¹ (concluded)	
1 Most sensitive of 50 spp tested		5 Least sensitive of 50 spp tested		9 <i>Pleurochaete squarrosa</i> , Montpelier	105-110
2 <i>Frullania dilatata</i> , Lake Garda	70-75	6 <i>Barbula gracilis</i> , Montpelier	110-115	Minimum Temperature²	
3 <i>Gymnomitrium obtusum</i>	65-70	7 <i>Ceratodon purpureus</i>	100-105	10 Majority of 30 spp tested	-10 to -20
4 <i>Plagiothecium curvifolium</i>	65-70	8 <i>Grimmia trichophylla</i>	105-110	11 Least sensitive of 30 spp tested ³	-20 to -30
5 <i>P. denticulatum</i>	70-75				

/1/ Injury observed after 30 min heating in dry state over phosphorus pentoxide. /2/ Duration, 18 hr in turgescence state during winter. /3/ Species include: *Ceratodon purpureus*, *Dicranum scoparium*, *Grimmia pulvinata*, *Plagiothecium denticulatum*, *P. undulatum*.

377. TEMPERATURE CHARACTERISTICS: PLANTS (Continued)
Part VII: TOLERANCE TO EXTREMES OF HEAT AND COLD: FLOWERING PLANTS

Plant		Temperature °C	Plant		Temperature °C
Maximum Temperature ¹			Winter-conditioned Plants ⁴ (concluded)		
Hydrophytes			Oat (Avena sativa)		
1	Elodea (Elodea callitrichoides)	38.5	29	Potato (Solanum tuberosum)	-9 to -12
2	Elodea (E. canadensis)	39-39.5	30	Rape (Brassica napus)	-2 to -3
3	Parrot's feather (Myriophyllum verticillatum)	40	31	Rye (Secale cereale)	-9
4	Vallisneria (Vallisneria spiralis)	41.5	32	Wheat (Triticum aestivum)	-15 to -25
Shade plants			33	Tree fruits: flowers ⁶	-10 to -22
5	Oxalis (Oxalis acetosella)	40.5	34	Apple (Pyrus malus)	-1.7 to -2.2
6	Impatiens (Impatiens parviflora)	41.5	35	Apricot (Prunus armeniaca)	-0.6 to -2.9
Herbaceous plants: xerophytic habitat			36	Cherry (Prunus sp)	-1.1 to -2.2
7	Ceterach (Ceterach officinarum)	48	37	Peach (P. persica)	-1.1 to -2.8
8	Fescue (Festuca glauca)	50.5	38	Pear (Pyrus communis)	-1.1 to -2.2
9	Germander (Teucrium chamaedrys)	48	39	Plum (Prunus sp)	-0.6 to -2.2
10	Germander (T. montanum)	48.5	Tree fruits: fruit set		
11	Hawkweed (Hieracium pilosella)	50.5	40	Apple (Pyrus malus)	-1.1 to -2.2
12	Iris (Iris chamaeiris)	49.5	41	Apricot (Prunus armeniaca)	0 to -2.2
13	Mullein (Verbascum thapsus)	48.5	42	Cherry (Prunus sp)	-1.1 to -2.2
14	Opuntia (Opuntia sp)	63	43	Peach (P. persica)	-1.1 to -2.8
15	Pink (Dianthus carthusianorum)	48	44	Pear (Pyrus communis)	-1.1 to -2.2
16	Sedum (Sedum acre)	48.5-49.5	45	Plum (Prunus sp)	-0.6 to -2.2
17	Sedum (S. reflexum)	49.5-50	Trunk cortex		
18	Sedum (S. spurium)	48.5	46	Apple (Pyrus malus)	
19	Thorn apple (Datura stramonium)	47	47	In January	-29
Minimum Temperature			47	Flowering period	-8
20	Achimene (Achimenes patens) ²	1-5	48	Apricot (Prunus armeniaca)	
21	Coleus (Coleus spp) ³	>1	49	In January	-21
22	Episcia (Episcia cupreata) ²	1-5	50	Flowering period	-6 to -7
23	Gloxinia (Gloxinia grandiflora) ²	1-5	51	Cherry (Prunus sp)	
24	Peperomia (Peperomia arifolia) ³	>1	51	In January	-23
25	Sultana (Impatiens sultani) ³	>1	52	Flowering period	-8
Winter-conditioned Plants⁴			Deciduous trees (29 species)⁷		
Cereal and field crops⁵			52	Buds opening (May 15)	-3 to -4
26	Barley (Hordeum vulgare)	-10 to -15	53	Resting buds (January)	
27	Beet (Beta vulgaris)	-5 to -7	54	Majority of spp tested	-20 to -22
28	Cabbage (Brassica oleracea capitata)	-8 to -11	55	Filbert (Corylus avellana)	Below -20
			55	Walnut (Juglans regia)	Below -20

/1/ More than 50% of test plants (50+ species) uninjured after 30 min heating in an atmosphere of saturated humidity. In dry atmosphere maximum tolerated temp is 2-5°C greater. /2/ Endures exposure up to 24 hr in an atmosphere of saturated humidity. Further exposure results in injury to leaves and, later, shoot apex. /3/ Injury observed after 28 hr at 0.3-1°C. /4/ Plants previously conditioned to low temp. /5/ Experimental temp for conditioned tissues. Data may be useful for estimating winter-cold resistance. /6/ Reported to endure -2.3 to 2.7°C for 30 min. /7/ 12-hr exposure.

Part VIII: LOW TEMPERATURE TOLERANCE: FLOWERING PLANTS

Winter-conditioned plants were exposed to experimental temperatures indicated in winter column; actively growing plants (in summer season) were observed under experimental temperatures shown in summer column.¹

Plant		Temperature °C		Plant		Temperature °C	
		Winter	Summer			Winter	Summer
Evergreen species (Riva-Gardasee)				Evergreen dwarf Alpine shrubs (Innsbruck) (concluded)			
1	Chamaerops (Chamaerops humilis)	-12 to -14	-10 to -12	15	Heather (Calluna vulgaris)	-28	-5
2	Fortune's palm (Trachycarpus fortunei)	-12.5 to -15	-10 to -13	16	Loiseleuria (Loiseleuria procumbens)	-35	-9
3	Laurel (Laurus nobilis)	-10 to -10.5	-6	17	Rhododendron (Rhododendron ferrugineum)		
4	Oak (Quercus ilex)	-13 to 13.5	-6	18	In protected position	-15	-5
5	Oleander (Nerium oleander)	-9	-4 to -6	19	In exposed position	-25	-5
6	Olive (Olea europaea)	-12	-6.5	20	Rhododendron (R. hirsutum)	-28.5	-5.5
7	Strawberry-tree (Arbutus unedo)	-10	-5 to -8	21	Conifers of Alpine Timberline (Innsbruck)		
8	Trifoliolate-orange (Poncirus trifoliata)	-18 to -22	-12 to -16	22	Pine (Pinus cembra)	below -39	-10
9	Viburnum (Viburnum tinus)	-11 to -12	-4 to -7	23	Pine (P. montana)	-35	-6
Conifers (Riva-Gardasee)				24	Spruce (Picea excelsa)	-38	-8 to -9
10	Cedar (Cedrus atlantica, C. deodara)	-15 to -17	-6 to -8	25	Conifers of Moscow Mountains (Idaho) ²		
11	Cypress (Cupressus sempervirens)	-14 to -18	-7 to -9	26	Fir (Abies grandis)	-45 to -55	-15
12	Pine (Pinus pinea)	-11 to -14	-5 to -7	27	Pine (Pinus ponderosa)	-50 to -60	-15
Evergreen dwarf Alpine shrubs (Innsbruck)				Field weeds			
13	Bear-berry (Arctostaphylos uva-ursi)	-29	-9	28	Chickweed (Stellaria media)	-9.7	-2.5
14	Heath (Erica carnea)	-18.5	-4.5	29	Ironweed (Veronica tournefortii)	-10.8	-4.3

/1/ 15-20% injury observed after 2-3 hr at indicated temp, and slow freezing and thawing for several hr with mature 1-2 yr old leaves of adult plants. No injury observed at 1-2°C higher temp. Resting buds reported to be more tolerant to low temp than leaves. /2/ Slight injury observed after exposure of a few min.

Part IX: TEMPERATURE RANGE OF METABOLIC ACTIVITY: PLANTS

Temperature values, unless otherwise specified, are lower and upper limits within which the specified activity was observed.

Plant		Activity	Temp °C	Plant		Activity	Temp °C
Algae				Flowering Plants (concluded)			
1	Chlamydomonas nivalis	Photosynthesis	-10 to 10	14	Bean, kidney (Phaseolus multiflorus)	Carbohydrate translocation	1 to 6 ⁵
2	Chlorella (Chlorella pyrenoidosa)			15	Cherry laurel (Prunus laurocerasus)	Photosynthesis	-6 to 37
3	Strain Emerson	Growth	25 ¹ , 29 ²	16	Chickweed (Stellaria media)	Photosynthesis	-10 to 35
4	Strain Tx 71105	Growth	39 ¹ , 41 ²	17	Coconut (Cocos nucifera)	Growth	10 to 30
5	Strain Emerson	Photosynthesis	32 ³ , 39 ⁴	18	Corn (Zea mays)	Growth	9.5 to 46
6	Strain Tx 71105	Photosynthesis	41 ³ , 45 ⁴	19	Date (Phoenix dactylifera)	Chlorophyll formation	13 to 14 ⁵
7	Strain Emerson	Respiration	30 ³ , >45 ⁴	20	Fir, arctic (Abies excelsa)	Photosynthesis	10 to 54
8	Strain Tx 71105	Respiration	41 ³ , >50 ⁴	21	Morning glory (Ipomoea spp)	Photosynthesis	-40 to 30
9	Dunaliella salina	Protoplasmic streaming	-19 to 40	22	Pea (Pisum sativum)	Respiration	10 to 60
10	Mastigocladus laminosus	Growth	5 to 60	23	Pumpkin (Cucurbita pepo)	Growth	-2 to 40
11	Nitella syncarpa	Protoplasmic streaming	0 ⁵	24	Wheat (Triticum aestivum)	Protoplasmic streaming	11 to 12 ⁵
12	Phaeosphaera perforata	Growth	4 to 10	25	Wheat (T. ferruginum)	Growth	5 to 42
Lichens				26		Chlorophyll formation	2 ⁵
12	Reindeer (Cladonia rangiferina)	Photosynthesis	-20 to 38				
Flowering Plants							
13	Barley (Hordeum vulgare)	Growth	5 ⁵				

/1/ Optimum temperature for continuous growth. /2/ Maximum temperature for continuous growth. /3/ Optimum temperature in experiments of short duration. /4/ Maximum temperature in experiments of short duration. /5/ Minimum temperature.

377. TEMPERATURE CHARACTERISTICS: PLANTS (Concluded)

Part X: LOWER TEMPERATURE LIMITS OF PHOTOSYNTHESIS

Lines 1, 2, and 4 apply to the Alpine timberline (1900 m), Innsbruck in May; all others at 600 m in April.

Plant		Temperature, °C						Plant		Temperature, °C							
		1	-1	-2	-3	-4	-5			-6	1	-1	-2	-3	-4	-5	-6
1	Pinus cembra	+	-						6	Pinus silvestris	+	+	+	-			
2	Arctostaphylos uva ursi	+	+	-					7	Taxus baccata	+	+	+	50%	-		
3	Buxus japonica	+	+	50%	-				8	Veronica persica	+	+	+	50%	-		
4	Picea excelsa	+	+						9	Picea excelsa	+	+	+	+	-		
5	Erica carnea	+	+	50%	-				10	Viscum album	+	+	+	50%	-		
									11	Hedera helix	+	+	+	+	67%	50%	-

Part XI: TEMPERATURE REQUIREMENTS FOR SPECIFIC CROPS

Data adapted from "Climate and Man," Yearbook of Agriculture, 1941. Values are broad generalizations and do not take into account such variables as day-night temperature differentiation, variety differences, physiological responses for which the optima are different from those for growth, and, in some instances, length of time during which temperatures above or below tolerance limit may persist. However, in many cases, data in this part may be correlated with that in other parts of this table and in other tables in this series.

Plant	Specification
Very Hardy Cool-season Crops	
1 Beet, garden (<i>Beta vulgaris</i>) ¹	Optimum vegetative growth at 16-21°C (60-70°F); tolerates repeated mild freezing temperatures at market stage. At >21°C (>70°F) growth is retarded.
2 Broccoli, sprouting (<i>Brassica oleracea botrytis</i>)	Similar to cabbage. Yield and quality reduced at mean temperature of >16°C (>60°F).
3 Brussels sprouts (<i>B. oleracea gemmifera</i>); collards, kale (<i>B. oleracea acephala</i>)	Tolerant to freezing temperatures at market stage; cool temperatures improve quality. Intolerant to monthly means of >21°C (>70°F).
4 Cabbage (<i>B. oleracea capitata</i>) ²	Optimum vegetative growth at 16-21°C (60-70°F). At >21°C (>70°F) plants remain vegetative, with slow, abnormal growth. Plants in head-stage are tolerant to frost, intolerant to freezing temperatures. Young, stocky, well-hardened plants, with stem 5-8 mm in diameter, survive winter temperature of -18°C (0°F) for short periods; larger or smaller plants are less hardy; larger surviving plants are likely to produce flowering stalks, instead of heading, in spring. Plants in active growing condition are intolerant to sudden freezing temperatures.
5 Spinach (<i>Spinacia oleracea</i>)	Optimum vegetative growth at 10-16°C (50-60°F). Fall-sown plants having a few well-developed leaves at the onset of cold weather are tolerant to subfreezing temperatures for many weeks; small seedlings and plants approaching maturity are less hardy. Sudden warm temperatures in spring terminate vegetative growth of plants overwintered or spring planted. At 21-27°C (70-80°F) crinkling and sturdy leaf growth reduced.
6 Turnip (<i>Brassica rapa</i>); rutabaga (<i>B. napus napobrassica</i>)	Optimum temperature similar to cabbage. Immature plants are more tolerant than cabbage to short periods at 4°C (40°F); mature plants more tolerant to mild freezing temperatures. At 24°C (75°F) growth rate is reduced, leaves injured.
Less Hardy Cool-season Crops	
7 Carrot (<i>Daucus carota</i>)	Optimum temperature 16-21°C (60-70°F); in seeding stage is more sensitive to temperature extremes. Leaves are damaged at freezing temperatures. Best color and highest carotene content occur at 10-16°C (50-60°F) (crop yield low). Normal growth does not occur between <10 (<50°F) and >21°C (>70°F).
8 Cauliflower, heading broccoli (<i>Brassica oleracea botrytis</i>)	Optimum temperature 16-21°C (60-70°F); less tolerant to temperature extremes than cabbage. Above 21°C (70°F) leafy, loose, or yellowed curds develop.
9 Celery (<i>Apium graveolens dulce</i>)	Optimum temperature 16-21°C (60-70°F). Treatment at 4-10°C (40-50°F) for 10 days conducive to flowering instead of normal growth. Prompt flowering (under chilled conditions) proportional to age of plant.
10 Lettuce (<i>Lactuca sativa</i>)	Optimum temperature 13-18°C (55-65°F). At 21-27°C (70-80°F) heading is prevented, plants flower. At constant temperature of 21°C (70°F) tip-burn is serious. High temperature conducive to development of bitter flavor. Small immature plants tolerant to mild freezing temperatures but mature plants are injured.
11 Pea, garden (<i>Pisum sativum</i>)	Optimum temperature 13-18°C (55-65°F); more seriously injured by frost than cabbage; slight freezing temperatures may injure or destroy flowers and fruits. At >27°C (>80°F) premature ripening of fruit occurs.
12 Potato (<i>Solanum tuberosum</i>)	Most rapid development of young sprouts at constant temperature of 24°C (75°F), later growth best at 18°C (64°F). At soil temperature of >24°C (>75°F), there occurs excessive branching of young sprouts, shortening of internodes, decrease in segmentation of leaves, diminution in stem diameter. At constant temperature of 20°C (68°F) tuber production is decreased with complete inhibition at 29°C (84°F). Below -1°C (30.2°F) tubers are injured.
Adapted to a Wide Range of Temperature and Tolerant to Frost	
13 Onion (<i>Allium cepa</i>)	Fairly low temperatures best for early stages of growth; for bulbing, fairly high temperatures, 16-21°C (60-70°F). Bulbing is influenced by day length. At 10-16°C (50-60°F) flowers are initiated; at 21-27°C (70-80°F), no flowering.
Adapted to a Wide Range of Conditions but not Tolerant to Frost¹	
14 Bean (<i>Phaseolus</i> spp.) ³	Optimum temperature 16-21°C (60-70°F).
15 Corn (<i>Zea mays</i>)	Optimum: mean summer temperature 21-27°C (70-80°F), night temperature, >14°C (>58°F). Date of flowering much earlier at 27°C (80°F) than at 21°C (70°F); retarded flowering at 16°C (60°F).
16 Cucumber (<i>Cucumis sativus</i>), Muskmelon (<i>C. melo</i>)	Optimum temperature 18-24°C (65-75°F).
17 Pepper, hot (<i>Capsicum</i> sp)	Tolerates higher temperature than sweet pepper.
18 Pepper, sweet (<i>Capsicum</i> sp)	Temperature requirements are a little higher than those for tomato, but more sensitive to chilly, wet weather in the spring and more tolerant to high summer temperatures. At 27°C (80°F) fruit set poor; constant temperature below 16°C (60°F) or above 32°C (90°F), complete barrenness.
19 Tomato (<i>Lycopersicon esculentum</i>)	Optimum temperature 21-24°C (70-75°F); tolerance extremes, 18-27°C (65-80°F). A constant temperature of 24°C (75°F), almost complete barrenness.
Warm Region Crops	
20 Eggplant (<i>Solanum melongena esculentum</i>)	Minimum temperature 18-21°C (65-70°F).
21 Sweetpotato (<i>Ipomoea batatas</i>)	Very sensitive to frost; minimum temperature 21°C (70°F).
22 Watermelon (<i>Citrullus vulgaris</i>)	Long growing season with high temperatures required.
Perennial Crops	
23 Asparagus (<i>Asparagus officinalis</i>)	Stem elongation rapid at 25°C (78°F), greatly retarded at 11°C (52°F). Early development of lateral branches at 35-40°C (95-105°F).
24 Rhubarb (<i>Rheum raphaniticum</i>)	Injured at -3 to -4°C (25-27°F), but intolerant to high temperatures of southern U.S.A. Development of pink color occurs at low temperatures and green color at high temperatures.

/1/ Cold, wet weather, even though frost-free, is harmful. Should not be planted until monthly means have reached 16-18°C (60-65°F). /2/ Biennial; after first growing period requires a dormant period at low temperature for initiation of flower stalk and flowers. /3/ Includes lima, string and many others.

378. VITALITY TESTS: SEEDS

Test	Seeds	Specification	Interpretation or Results
Biochemical Tests			
1 Indigo carmine, 0.05%	Pine	Stain for 2 hr, 20°C.	Embryo uncolored to 1/4 colored = viable.
2 Phenol, 1%	Wheat	Stain for 25 hr, 15°C.	
3 Tetrazolium, 1%	Various spp.	Stain for 24 hr (in dark), 20°C.	
4 NaHSeO ₃ , 2%	Agricultural spp.	Stain for 16 hr + 8 hr with aeration.	Embryo red = viable.
5 Na ₂ TeO ₄	Various spp.	Treat in H ₂ O for 24 hr, 20°C; remove seed coat; stain for 48 hr.	Embryo black = viable.
7 Meta-dinitrobenzene	Rye, wheat	Oxidation-reduction: treat for 5 hr, 20°C.	Seed purple in NH ₃ = viable.
8 KOH	Tropical spp.		Seed discolored = dead.
9 KI, 1.3%	Spruce	Treat for 8 hr, 20°C; then incubate for 24 hr.	Seed deep purple = viable.
10 I, 0.3%	Pine		
11 Oxidase activity	Various spp.	Crush and treat in 0.1% guaiac resin.	Seed blue or violet = viable.
Embryo Culture			
12 Nutrient culture	Various spp.	Knop's medium + glucose, agar; for 7 da, 20°C.	Growth of embryo directly proportional to actual germination.
13 Filter paper		Moisten with H ₂ O, 5-10 da, 21-23°C.	
Physical Tests			
14 Cutting and crushing	Thin, soft coated	Cutting: treat in water.	Seed firm, free from discoloration = viable.
15	Heavy coated	Crushing: stratify for 4 wk.	
16 Visual	Birch	Transparency.	Embryo undeveloped, shrunken = immature.
	Pine, spruce	Embryo-ratio.	Embryo length-seed length ratio < 0.8 = immature.
18 Specific gravity	Pine	In water.	Floating seed = dead. ¹
	Spruce	In alcohol	
20 Electric conductivity	Grasses	"Blaze current" proportional to viability; rise in conductivity proportional to % dead seed.	
21 Heat of respiration	All species	Aseptic incubation.	Temp. increase proportional to germinative energy.

/1/ Floating seeds are almost invariably non-viable; however, sinking is not necessarily an indication of viability.

379. CONDITIONS FOR SEED GERMINATION: HERBACEOUS PLANTS

Species	Temp. ¹ °C	Dura- tion ² da	Specifications ³	Species	Temp. ¹ °C	Dura- tion ² da	Specifications ³
Agricultural Crops				Vegetable Crops (concluded)			
1 Alfalfa (<i>Medicago sativa</i>)	20	4-7	B, S	46 Celery (<i>Apium graveolens</i> dulce)	20-30	10-21	P, TB; light, KNO ₃ ⁹
2 Barley (<i>Hordeum vulgare</i>)	20	4-7	T, S; prechill ⁴	47 Cucumber (<i>Cucumis sativus</i>)	20-30	3-7	T, S, B
3 Bean, field (<i>Phaseolus vulgaris</i>)	20-30	5-8	R, S	48 Dandelion (<i>Taraxacum officinale</i>)	20-30	7-21	P, TB; light
4 Beet (<i>Beta vulgaris</i>)	20-30	3-14	B; H ₂ O soak ⁵	49 Eggplant (<i>Solanum melongena</i> escul.)	20-30	7-14	TB
5 Bentgrass (<i>Agrostis tenuis</i>)	20-30	7-28	P; light, KNO ₃	50 Endive (<i>Cichorium endiva</i>)	20-30	5-14	P, TS
6 Bermuda grass (<i>Cynodon dactylon</i>)	20-35	7-21	P; light, KNO ₃	51 Kale (<i>Brassica oleracea acephala</i>)	20-30	3-10	B, P ¹¹
7 Bluegrass (<i>Poa pratensis</i>)	15-30	10-28	P; light, KNO ₃ ⁶	52 Lettuce (<i>Lactuca sativa</i>)	20	7	P; light, prechill ¹²
8 Buckwheat (<i>Fagopyrum esculentum</i>)	20-30	3-6	B, T	53 Muskmelon (<i>Cucumis melo</i>)	20-30	4-10	B, T, S ¹³
9 Canary grass (<i>Phalaris canariensis</i>)	20-30	3-7	B	54 Okra (<i>Hibiscus esculentus</i>)	20-30	4-21	R
10 Clover (<i>Trifolium spp</i>) ⁷	17-18 ⁸	4-7	B, S	55 Onion (<i>Allium cepa</i>)	20	6-12	B, S
11 Corn (<i>Zea mays</i>)	20-30	4-7	R, S	56 Parsley (<i>Petroselinum hortense</i>)	20-30	11-28	B
12 Cotton (<i>Gossypium spp</i>)	20-30	4-12	R, S	57 Parsnip (<i>Pastinaca sativa</i>)	20-30	6-28	B
13 Cowpea (<i>Vigna sinensis</i>)	20-30	5-8	R, S	58 Pea, garden (<i>Pisum sativum</i>)	20	5-8	R, S
14 Crotalaria (<i>Crotalaria spp</i>)	20-30	4-10	B, S	59 Pepper (<i>Capsicum spp</i>)	20-30	6-14	TB
15 Dallis grass (<i>Paspalum dilatatum</i>)	20-35	7-21	P; light, KNO ₃	60 Pumpkin (<i>Cucurbita spp</i>)	20-30	4-7	T, S ¹³
16 Festuca (<i>Festuca arundinacea</i>)	20-30	5-14	P; light	61 Radish (<i>Raphanus sativus</i>)	20	4-6	B
17 Fescue (<i>F. elatior</i>)	20-30	5-14	P; light	62 Rhubarb (<i>Rheum raphaniticum</i>)	20-30	7-21	TS; light
18 Flax (<i>Linum usitatissimum</i>)	20-30	3-7	B, S	63 Rutabaga (<i>Brassica napus napob.</i>)	20-30	3-14	B
19 Hemp (<i>Cannabis sativa</i>)	20-30	3-7	B	64 Spinach (<i>Spinacia oleracea</i>)	10	7-21	TB ¹³
20 Johnson grass (<i>Sorghum halepense</i>)	20-35	7-35	P; light, KNO ₃	65 Squash (<i>Cucurbita spp</i>)	20-30	4-7	T, S ¹³
21 Lespedeza (<i>Lespedeza stipulacea</i>)	20-35	5-14	B	66 Tomato (<i>Lycopersicon esculentum</i>)	20-30	5-14	B ¹⁴
22 Lupine (<i>Lupinus angustifolius</i>)	20	4-10	R, S	67 Turnip (<i>Brassica rapa</i>)	20-30	3-7	B
23 Mustard (<i>Brassica nigra</i>)	20-30	3-7	P; light, KNO ₃ ⁹	68 Watermelon (<i>Citrullus vulgaris</i>)	20-30	4-14	T, S ¹³
24 Oat (<i>Avena sativa</i>)	20	5-10	T, S; prechill ⁴	Flowers			
25 Orchardgrass (<i>Dactylis glomerata</i>)	20-30	7-21	P, S; light	69 Aster, annual (<i>Aster spp</i>)	20	8	TB
26 Pea, field (<i>Pisum sativum arvense</i>)	20	3-8	R, S	70 Balsam (<i>Impatiens balsamina</i>)	20	8	TB; light, KNO ₃
27 Peanut (<i>Arachis hypogaea</i>)	20-30	5-10	R, S	71 Canterbury bell (<i>Campanula spp</i>)	20-30	6-12	TB
28 Redtop (<i>Agrostis alba</i>)	20-30	5-10	TB, P; light	72 Carnation (<i>Dianthus caryophyllus</i>)	20	8	TB
29 Rice (<i>Oryza sativa</i>)	20-30	5-14	B, T	73 Cornflower (<i>Centaurea cyanus</i>)	15	4-8	TB
30 Rye (<i>Secale cereale</i>)	20	4-7	T, S; prechill ⁴	74 Cosmos (<i>Cosmos spp</i>)	20-30	3-8	TB; light, KNO ₃
31 Ryegrass (<i>Lolium multiflorum</i>)	20-30	5-14	P, TB; light, KNO ₃	75 Dahlia (<i>Dahlia spp</i>)	20-30	4-10	TB
32 Sesame (<i>Sesamum orientale</i>)	20-30	3-6	P	76 Daisy (<i>Chrysanthemum maximum</i>)	20-30	8	TB; light
33 Sorghum (<i>Sorghum vulgare</i>)	20-30	4-10	B, S; prechill ⁴	77 Forget-me-not (<i>Myosotis spp</i>)	20	5-12	TB
34 Soybean (<i>Glycine soja</i>)	20-30	5-8	R, S	78 Hollyhock (<i>Althaea rosea</i>)	20	5-18	B
35 Sunflower (<i>Helianthus annuus</i>)	20-30	3-7	T, B	79 Larkspur (<i>Delphinium spp</i>)	15	10-21	TB
36 Timothy (<i>Phleum pratense</i>)	20-30	5-10	P, TB; light, KNO ₃	80 Marigold (<i>Tagetes spp</i>)	20-30	7	TB
37 Tobacco (<i>Nicotiana tabacum</i>)	20-30	7-14	P, TB; light	81 Nasturtium (<i>Tropaeolum spp</i>)	18	14	R
38 Wheat (<i>Triticum spp</i>)	20	4-7	T, S; prechill ⁴	82 Pansy (<i>Viola tricolor</i>)	20	12	TB
39 Wheatgrass (<i>Agropyron cristatum</i>)	20-30	5-14	P, TB; light, KNO ₃ ¹⁰	83 Petunia (<i>Petunia spp</i>)	20-30	6-10	P; light
Vegetable Crops				84 Poppy (<i>Papaver orientale</i>)	20	6-12	TB
40 Asparagus (<i>Asparagus officinalis</i>)	20-30	7-21	T	85 Salvia (<i>Salvia splendens</i>)	20-30	4-12	TB; light
41 Bean (<i>Phaseolus coccineus</i>)	20-30	5-9	R, S	86 Snapdragon (<i>Antirrhinum spp</i>)	20-30	5-12	P; light ¹⁵
42 Bean (<i>P. lunatus macrocarpus</i>)	20-30	5-9	R, S, C	87 Stock (<i>Matthiola incana</i>)	20-30	7	TB; light
43 Broadbean (<i>Vicia faba</i>)	17-18	4-14	S, C ⁹	88 Sweetpea (<i>Lathyrus odoratus</i>)	18	12	R
44 Cabbage (<i>Brassica oleracea cap.</i>)	20-30	3-10	B, P ¹¹	89 Wallflower (<i>Cheiranthus allioni</i>)	20-30	4-10	TB; KNO ₃
45 Carrot (<i>Daucus carota</i>)	20-30	6-28	B	90 Zinnia (<i>Zinnia spp</i>)	20-30	3-7	TB; light

/1/ When a range is given, a daily fluctuating temperature is preferred, viz: 16 hours at lower temperature and 8 hours at higher temperature.

/2/ Maximum germination is usually obtained during the time limits as specified; for hard coated seeds an additional 5 days is recommended.

/3/ Substrata: B = between blotters; TB = top of blotters; T = between folded paper toweling; R = rolled towel; S = soil or sand; P = closed petri dish with cotton, blotter or filter paper; C = creped cellulose paper wadding. For KNO₃ treatment, a 0.2% solution, unless otherwise specified, is used to moisten substrata. /4/ Prechill at 5 or 10°C for 5 days. /5/ Soak in water for 2 hours, rinse, blot surface dry. /6/ Use 0.1% KNO₃. Prechill dormant seeds at 10°C for days. /7/ Species include: T, hybridum, T, incarnatum, T, pratense; T, repens, duration of 3-7 days. /8/ Dormant seed: 15°C. /9/ Prechill at 10°C for 3 days. /10/ Prechill at 5 or 10°C for 7 days. /11/ Dormant seed: light, KNO₃; prechill at 5 or 10°C for 3 days. /12/ Prechill at 10 or 15°C for 3 days. /13/ Substrata held somewhat drier than for the average kind of seed.

/14/ Dormant seed: light, KNO₃. /15/ Fresh and hybrid seed may require prechilling at 3 or 5°C for 10-20 days.

380. EFFECTIVE PRETREATMENT AND GERMINATION CONDITIONS, SEEDS: WOODY PLANTS

When shed by the plant, seeds of certain species normally undergo a dormant period before onset of germination. Dormancy may be broken by various appropriate treatments prior to planting. Pretreatments usually include exposure to cold and to moisture, and may also include partial or complete rupture of the seed coat by scarification. If, following pretreatments, conditions for germination are established, maximum germination occurs within the indicated interval.

Species	Pretreatment ¹		Germination		Species	Pretreatment ¹		Germination	
	Temp ² °C	Duration da	Temp ³ °C	Duration da		Temp ² °C	Duration da	Temp ³ °C	Duration da
Fruit and Nut Crops					Broadleaf Trees and Shrubs (concluded)				
1 Apple (<i>Pyrus malus</i>)	5	75	20-30	60	62 Oak (<i>Quercus imbricaria</i>)	0-5	30-60	16-24	30
2 Butternut (<i>Juglans cinerea</i>)	2-7	90-120	20-30	45-60	63 Oak (<i>Q. alba</i>)			20-30	30-50
3 Cherry (<i>Prunus avium</i> and <i>cerasus</i>)	0-5	90-120	20-30 ⁴	60	64 Peashrub (<i>Caragana</i> spp)	Water soaking ¹³		20-30	30-60
4 Chestnut (<i>Castanea dentata</i>)	0-5	90	15-26 ⁴	30-45	65 Poplar (<i>Populus</i> spp)			20-30	4-7
5 Hickory (<i>Carya</i> spp)	-1 to 7	90-150	20-30	30-60	66 Rhododendron (<i>Rhododendron</i> spp)			20-30	30-90
6 Mulberry (<i>Morus rubra</i>)	5	90-120	20-30	30-45	67 Rose (<i>Rosa</i> spp)	5 ¹⁴	120	20-30 ⁴	30 ⁴
7 Peach (<i>Prunus persica</i>)	2-7	45-90	20-30 ⁴	60	68 Serviceberry (<i>Amelanchier</i> spp)	2-5	90-180	20-30	40
8 Pear (<i>Pyrus communis</i>)	0-7	60-90	10	45	69 Sumac (<i>Rhus glabra</i>)	Scarification ¹⁵		20-30	30-60
9 Pecan (<i>Carya illinoensis</i>)	2-7	30-90	20-30	45-60	70 Sweetgum (<i>Liquidambar styraciflua</i>)	5	30-90	20-30	20-60
10 Persimmon (<i>Diospyros virg.</i>)	10	60-90	20-30	40-60	71 Sycamore (<i>Platanus occidentalis</i>)	2-5	45-60	20-30	15-20
11 Plum (<i>Prunus americana</i>)	5	150	10 ⁵	60	72 Tupelo (<i>Nyssa sylvatica</i>)	-1 to 10	60-90	20-30	30-60
12 Raspberry (<i>Rubus idaeus</i>)	20-30;	90	20-30	30	73 Yellow-poplar (<i>Liriodendron tulipifera</i>)	0-10	70	20-30	50-70
13	then 5 ⁶	90	20-30	30					
14 Walnut (<i>Juglans nigra</i>)	3	60-120	20-30	15-40	Conifers				
Broadleaf Trees and Shrubs					74 Alaska-cedar (<i>Chamaecyparis nootkatensis</i>)	5 ⁴	60-90 ⁴	20-30	60
15 Alder (<i>Alnus rubra</i>)	5 ⁴	30-60	20-30 ⁴ , 7	30-40	75 Baldcypress (<i>Taxodium distichum</i>)	5	30-60	20-30	30-50
16 Ash (<i>Fraxinus</i> spp) ⁸	5	60-90	20-30	40-60	76 Cedar (<i>Cedrus</i> spp)			20-30	30-40
17 Ash (<i>F. excelsior</i> , <i>F. nigra</i>)	20;	60-90	20-30	30-40	77 Cypress (<i>Cupressus arizonica</i>)	5	60	20-30	30
18	then 5 ⁶	60-90	20-30	30-40	78 Douglas-fir (<i>Pseudotsuga menziesii</i>) ¹⁶	1-5	30-60	16-30	15-30
19 Aspen (<i>Populus tremuloides</i>)	0-5	15-40	12-24	40	79 Fir (<i>Abies</i> spp) ¹⁶	5	60-90	20-30	30-45
20 Barberry (<i>Berberis</i> spp)	2-5 ⁹	110-130	18-29	30-60	80 Fir (<i>A. balsamea</i>)	5	90	20-30	60-120
21 Basswood (<i>Tilia americana</i>)	5	90	20-30	60	81 Fir (<i>A. grandis</i>) ¹⁷	5	30-40	20-30	30-45
22 Beech (<i>Fagus</i> spp)	0-10	30-60	20-30	30-40	82 Fir (<i>A. procera</i>)	1-5 ⁴	40-60	20-30	15-30
23 Birch (<i>Betula pendula</i>)	0-10	60-90	20-30	40	83 Hemlock (<i>Tsuga canadensis</i>)	5	60-120	20-30	60
24 Birch (<i>B. populifolia</i>)	5	60-75	15-32	30-40	84 Hemlock (<i>T. heterophylla</i>)	1-5	90	11-16	25-30
25 Birch (<i>B. papyrifera</i>)	0-5	40-70	15-32	30	85 Incense-cedar (<i>Libocedrus decurrens</i>)	2-5	60-90	15-27	40-60
26 Birch (<i>B. lenta</i>)	5	30-60	15-32	30-40	86 Juniper (<i>Juniperus scopulorum</i>)	20-30;	120	20-30	20-30
27 Birch (<i>B. alleghaniensis</i>)	5	90	10-25	50-60	87	then 5 ⁶	120	20-30	20-30
28 Boxelder (<i>Acer negundo</i>)	5	90	20-30	30-60	88 Larch (<i>Larix laricina</i>)	5	30-60	20-30	30-50
29 Catalpa (<i>Catalpa</i> spp)	5	90-120	20-30	30	89 Larch (<i>L. decidua</i>)	5	60	20-30	35
30 Cherry (<i>Prunus serotina</i>)	18-30;	60-120	20-30	60-90	90 Larch (<i>L. occidentalis</i>)	5	30	20-30	20-30 ⁴
31 Coffeetree (<i>Gymnocladus dioica</i>)	then 1-5 ⁶	60-90	20-30	60-90	91 Pine (<i>Pinus</i> spp) ¹⁸	10	30	20-30	30-40
32 Cottonwood (<i>Populus deltoides</i>)	5	30	20-30	30	92 Pine (<i>P. strobus</i>)			20-30	30-40
33 Crabapple (<i>Malus baccata</i>)	5	120	10	30	93 Pine (<i>P. jeffreyi</i>)	2-4	30-90	20-30	35-45
34 Crabapple (<i>M. coronaria</i>)	5	100-130	20-30	20-25	94 Pine (<i>P. taeda</i>)			15-27	30
35 Dogwood (<i>Cornus florida</i>)	0-5	120-200	20-30	40	95 Pine (<i>P. contorta</i>)			13-24	35
36 Dogwood (<i>C. nuttallii</i>)	5	90	20-30	20-40	96 Pine (<i>P. palustris</i>)	5	30	18-27	30
37 Elm (<i>Ulmus americana</i>)	5	60	20-30	13-60	97 Pine (<i>P. rigida</i>)	2-4	30-45	15-27	35-45
38 Elm (<i>U. thomasi</i>)	5	60-90 ⁴	20-30	50-70	98 Pine (<i>P. echinata</i>)	2-5	15-45	18-30	20-45
39 Elm (<i>U. rubra</i>)	5	60-90 ⁴	20-30	50-70	99 Pine (<i>P. elliotii</i>)	2-10	90	16-21	40
40 Eucalyptus (<i>Eucalyptus globulus</i>)	5	60-90	16-21 ¹⁰	10-15	100 Pine (<i>P. lambertiana</i>)	0-5	90	16-27	60-90
41 Hackberry (<i>Celtis</i> spp)	21-27;	60	16-27	60	101 Pine (<i>P. monticola</i>)	5 ⁴	30-60 ⁴	20-30	60
42 Hawthorn (<i>Crataegus mollis</i>)	then 5 ⁶	75-90	16-27	60	102 Port-Orford-cedar (<i>Chamaecyparis lawsoniana</i>)	25;	30	20-30	20
43 Honeylocust (<i>Gleditsia triacanthos</i>)	Scarification ¹¹	60	20-30	15-40	103 Redcedar (<i>Juniperus virginiana</i>)	then 5 ⁶	90	10-25	20-30
44 Honeysuckle (<i>Lonicera tatarica</i>)	5	30-60	20-30	60-90	104 Redcedar (<i>Thuja plicata</i>)	0-10	30-60	20-30	20
45 Hornbeam (<i>Carpinus caroliniana</i>)	2-7	100-120	16-27	45	105 Sequoia (<i>Sequoia</i> spp)	5	30-60	20-30	40-60
46 Locust (<i>Robinia pseudoacacia</i>)	Scarification ¹²	15-27	10-25	60	106 Spruce (<i>Picea mariana</i>)			20-30	20-30
47 Magnolia (<i>Magnolia grandiflora</i>)	5	90-120	15-26 ⁴	60	107 Spruce (<i>P. engelmannii</i>)	5	30-45	20-30	20-30
48 Maple (<i>Acer macrophyllum</i>)	5	60	20-30 ⁴	60 ⁴	108 Spruce (<i>P. abies</i>)	1-5	40	25	15
49 Maple (<i>A. rubrum</i>)	5	60-75	10-25	30-40	109 Spruce (<i>P. rubens</i>)	5	60-90	20-30	30-45
50 Maple (<i>A. saccharinum</i>)	3-5	60-90	20-30	30	110 White-cedar (<i>Chamaecyparis thyoides</i>)	5 ⁴	30-60	20-30	60
51 Maple (<i>A. saccharum</i>)	1-5	30-60	18-27	30-50	111 White-cedar (<i>Thuja occidentalis</i>)	0-10	30-60	20-30	30
52 Oak (<i>Q. macrocarpa</i>)	5	30-45	20-30	40					
53 Oak (<i>Q. prinus</i>)			18-27	60					
54 Oak (<i>Q. robur</i>)			16-25	30-60					
55 Oak (<i>Q. rubra</i>)	0-4	30-45	20-30	40-60					
56 Oak (<i>Q. coccinea</i>)	0-5	30-60	20-30	60					

/1/ When no treatment is specified, pretreatment is not required. /2/ When a range is given, the temperature may vary between the limits. /3/ When a range is given, a daily fluctuating temperature, 16 hr at lower temperature and 8 hr at higher temperature, is preferred. /4/ Suggested treatment, experimental data incomplete. /5/ Seeds from southern USA germinate best at 21-27°C. /6/ Treatment at high temperature is followed by treatment at low temperature. /7/ Germination data also applicable to European alder (*A. glutinosa*), pretreatment not required. /8/ Species include: green ash (*F. pennsylvanica*), white ash (*F. americana*). /9/ Prior to stratification soak 3 da in water, surface dry, then digest 40 min in concentrated H₂SO₄ (below 55°C), wash and extract seeds. Place dry seed in concentrated H₂SO₄ for 10-15 min. /10/ Constant temperature between these limits is preferred. /11/ Scarify with concentrated H₂SO₄ (25-36°C) for 1-2 hr prior to planting. /12/ Scarify with concentrated H₂SO₄ (16-27°C) for 20-120 min prior to planting. /13/ Soak seed in water at 21°C for 12 hr prior to planting. /14/ Scarify with concentrated H₂SO₄ for 60-80 min prior to planting. /15/ Scarify with concentrated H₂SO₄ for 1-4 hr prior to planting. /16/ Data applicable to Pacific silver fir (*A. amabilis*), white fir (*A. concolor*); for California red fir (*A. magnifica*), with a duration of pretreatment modified to 60 days. /17/ Data also applicable to Fraser fir (*A. fraseri*), cf Fn 4. /18/ Species include: ponderosa pine (*P. ponderosa*), red pine (*P. resinosa*), Scotch pine (*P. sylvestris*); jack pine (*P. banksiana*), with duration of germination modified to 15-60 days.

381. RESISTANCE TO WILTING

Plants may grow within a wide range of soil moisture conditions, but at a definite moisture limit, known as the wilting coefficient (permanent wilting percentage), the plant is unable to overcome the resistance of soil to water removal. The wilting coefficient is the moisture content of the soil, expressed as a percentage of dry weight, at the time when the leaves of the plant first undergo a permanent reduction in moisture content (resulting from soil moisture deficiency). At this condition the leaves cannot recover in an approximately saturated atmosphere without the addition of water to the soil. In Part I, free energy values indicate soil's resistance (to removal of water) that plants would have to overcome at various moisture levels. Part II shows that all plants wilt at relatively the same moisture content in a given soil. Sampling error varies with completeness with which the roots contact the soil mass. Cocklebur, for example, may have relatively few coarse roots whereas alfalfa has very many fine absorbing-roots. Part III gives wilting coefficients as determined from small or large soil containers. Part IV demonstrates that repeated wiltings do not increase the ability of plants to take more water from soil. Part V reveals the constancy and recurrence of wilting coefficient in the field; determinations were made in the same orchard for many years. Soil moisture is reduced to essentially the same per cent annually, and plants do not become more resistant to wilting with increase in age. Differences in root distribution influence wilting percentages. Part VI denotes that wilting coefficient is not affected by evaporation conditions antecedent to wilting, or by soil temperature within the minimum and maximum range likely to be encountered during the growing season. Part VII gives the depths to which the roots of mature crops might exhaust the water supply when grown in a deep, permeable, well-drained soil, having little horizon formation. The survival of certain plants under severe conditions of drought may depend, in part, on the depth of rooting and thoroughness with which the roots permeate soil and not on the capacity to extract more water from soil than other plants.

Part I: FREE ENERGY PER GRAM OF WATER: VARIOUS SOIL MOISTURE CONTENTS AT 30°C

Soil Moisture ¹	Vapor Pressure mm Hg	Relative Humidity %	Energy ² ergs
Fine Sandy Loam			
1	10.5	31.7	99.7
2	9.3	31.7	99.7
3	5.9	31.6	99.4
4	5.4	31.4	98.7
5	4.6	31.4	98.7
6	3.0	31.4	98.7
7	1.7	30.8	96.7
8	1.6	30.3	95.3
9	1.2	27.5	86.5
10	0.9	24.9	78.3
11	0.8	23.3	73.3
12	0.7	17.9	56.3
Clay Soil			
13	27.0	31.6	99.4
14	21.6	31.5	99.1
15	18.6	31.3	98.4
16	13.1	31.3	98.4
17	10.9	31.1	97.8
18	10.8	30.6	96.2
19	10.1	29.3	92.1
20	9.6	28.1	88.4
21	9.0	26.5	83.1
22	8.7	25.3	79.6
23	8.5	24.0	75.5
24	8.4	22.9	72.0
25	7.9	18.2	57.2
26	7.8	17.0	53.5

¹/1/ Grams water per 100 g soil. ²/2/ Free energy per g water x 10⁶.

Part III: WILTING COEFFICIENT: VARIOUS SOIL CONTAINERS

Plants	Soil Container	Wilting %	Availability Ratio ¹
Oakley Fine Sand (3.29) ²			
1 Sunflower	10-quart	1.41	2.33
2 Corn	10-quart	1.35	2.44
3 Sunflower	Small ³	1.24	2.65
4 Corn	Small ³	1.36	2.42
5 Miscellaneous ⁴	10-quart	1.29	2.55
Yolo Fine Sandy Loam (16.80) ²			
6 Miscellaneous ⁴	10-quart	8.67	1.98
7 Miscellaneous ⁴	Tank ⁵	9.88	1.74
Yolo Fine Sandy Loam (18.49) ²			
8 Sunflower	10-quart	9.78	1.89
9 Corn	10 quart	9.67	1.91
10 Sunflower	Small ³	10.06	1.84
11 Corn	Small ³	10.33	1.79
Yolo Silt Loam (21.35) ²			
12 Sunflower	10-quart	10.25	2.08
13 Corn	10-quart	10.28	2.08
14 Sunflower	Small ³	10.38	2.05
15 Corn	Small ³	10.71	2.00
16 Miscellaneous ⁴	10-quart	9.95	2.15
Yolo Clay (28.03) ²			
17 Sunflower	10-quart	13.35	2.10
18 Corn	10-quart	13.13	2.13
19 Sunflower	Small ³	14.48	1.94
20 Corn	Small ³	14.46	1.94
21 Miscellaneous ⁴	10-quart	12.65	2.22

¹/1/ Ratio of moisture equivalent, cf Fn 2, and permanent wilting; indicates the range of available water. ²/2/ Moisture equivalent, i.e., percentage water content that a soil can retain in opposition to a force 1000 times that of gravity, is enclosed in parentheses. ³/3/ Cannery cans containing about 550 g soil. ⁴/4/ Include cotton, sorghum, guar, mustard, black-eye and mungbeans. ⁵/5/ Tanks contained 1000 to 2000 lbs soil.

Part VI: WILTING COEFFICIENT: SHADE AND FULL SUNLIGHT

Soil	Plant	Wilting %	
		In Shade	In Sun
1 Oakley fine sand	Sunflower	1.3	1.4
2	Corn	1.3	1.4
3	Sunflower	14	13.7
4 Yolo clay	Corn	13.5	14.1
5	Sunflower	11	9.5
6	Corn	9.8	9.9
7	Sunflower	10.4	10.4
8	Corn	10.7	10.6
9	Sunflower	3.7	4.3
10	Corn	4.6	3.8
11 Sierra sandy loam	Corn	6	6.5
12	Sunflower	6.3	7.2
13	Corn	6.7	6.5

Part VII: DEPTH OF WATER EXTRACTION: MATURE PLANT ROOTS

Species	Root Depth Ft
1 Alfalfa (<i>Medicago sativa</i>)	10-15
2 Almond (<i>Prunus amygdalus</i>)	6-9
3 Apricot (<i>P. armeniaca</i>)	6-9
4 Artichoke (<i>Helianthus tuberosus</i>)	4.5
5 Asparagus (<i>Asparagus officinalis</i>)	10
6 Bean (<i>Phaseolus lunatus macrocarpus</i>)	4
7 Beet, garden (<i>Beta vulgaris</i>)	3
8 Beet, sugar (<i>B. vulgaris</i>)	5-6
9 Broccoli (<i>Brassica oleracea botrytis</i>)	2
10 Cabbage (<i>B. oleracea capitata</i>)	2
11 Cantaloupe (<i>Cucumis melo cantalupensis</i>)	4-6
12 Carrot (<i>Daucus carota</i>)	3
13 Cauliflower (<i>Brassica oleracea bot.</i>)	2
14 Celery (<i>Apium graveolens</i>)	2
15 Cherry (<i>Prunus spp</i>)	6-9
16 Citrus (<i>Citrus spp</i>)	6
17 Corn, field (<i>Zea mays</i>)	6
18 Corn, sweet (<i>Z. mays</i>)	3
19 Cotton (<i>Gossypium spp</i>)	6
20 Cucumber (<i>Cucumis sativus</i>)	3.5
21 Eggplant (<i>Solanum melongena</i>)	3
22 Fig (<i>Ficus carica</i>)	5
23 Flax (<i>Linum usitatissimum</i>)	6
24 Grape (<i>Vitis vinifera</i>)	8
25 Hop (<i>Humulus lupulus</i>)	4-6
26 Lettuce (<i>Lactuca sativa</i>)	1.5
27 Milo (<i>Sorghum vulgare</i>)	6
28 Mustard (<i>Brassica juncea</i>)	3.5
29 Olive (<i>Oleo europaeo</i>)	6-9
30 Onion (<i>Allium cepa</i>)	1
31 Parsnip (<i>Pastinaca sativa</i>)	4
32 Pea (<i>Pisum sativum</i>)	3.5
33 Peach (<i>Prunus persica</i>)	6-9
34 Pear (<i>Pyrus communis</i>)	6-9
35 Prune (<i>Prunus americana</i>)	6-9
36 Pepper (<i>Capsicum frutescens</i>)	3
37 Potato (<i>Solanum tuberosum</i>)	3
38 Pumpkin (<i>Cucurbita pepo</i>)	6
39 Radish (<i>Raphanus sativus</i>)	1.5
40 Spinach (<i>Spinacia oleracea</i>)	2
41 Squash (<i>Cucurbita pepo</i>)	3
42 Sudan grass (<i>Sorghum sudanense</i>)	>6
43 Tomato (<i>Lycopersicon esculentum</i>)	6-10
44 Turnip (<i>Brassica rapa</i>)	3
45 Strawberry (<i>Fragaria spp</i>)	3-4
46 Sweet potato (<i>Ipomoea batatas</i>)	4-6
47 Walnut (<i>Juglans spp</i>)	12-18
48 Watermelon (<i>Citrullus vulgaris</i>)	6

Part II: WILTING COEFFICIENT: CLAY SOIL

Species	Wilting %
1 Alfalfa (<i>Medicago sativa</i>)	13
2 Castor bean (<i>Ricinus communis</i>)	15
3 Cocklebur (<i>Xanthium canadense</i>)	15.6
4 Coleus (<i>Coleus blumei</i>)	14.2
5 Corn (<i>Zea mays</i>)	15
6 Fenugreek (<i>Trigonella foenum-graecum</i>)	15
7 Hollyhock (<i>Althaea rosea</i>)	14.2
8 Jimson-weed (<i>Datura tatula</i>)	15
9 Lettuce (<i>Lactuca sativa</i>)	14.6
10 Mallow (<i>Malva parviflora</i>)	13.4
11 Marigold (<i>Tagetes locida</i>)	13.6
12 Mung-bean (<i>Phaseolus aureus</i>)	14.7
13 Mustard (<i>Brassica alba</i>)	13.8
14 Okra (<i>Hibiscus esculentus</i>)	14.7
15 Pepper (<i>Piper capsicum</i>)	14.6
16 Petunia (<i>Petunia hybrida</i>)	13.5
17 Pigweed (<i>Amaranthus retroflexus</i>)	14.5
18 Salvia (<i>Salvia splendens</i>)	14.4
19 Sorghum (<i>Sorghum vulgare</i>)	14.2
20 Soybean (<i>Glycine soja</i>)	14
21 Spinach (<i>Spinacia oleracea</i>)	13.7
22 Sunflower (<i>Helianthus annuus</i>)	14
23 Thistle (<i>Silybum marianum</i>)	15
24 Wheat (<i>Triticum aestivum</i>)	13.6

Part IV: WILTING COEFFICIENT: SUNFLOWER

Soil	Percentages for Successive Wiltings					
	1st	2nd	3rd	4th	5th	6th
1 Oakley fine sand	1.6	1.5	1.5	1.6	1.5	1.5
2 Yolo fine sandy loam	9.5	9.4	9.4	9.3	9.2	9
3 Yolo silt loam	10.7	10.5	10.8	10.7	10.6	11
4 Yolo clay	13.4	13.8	13.8	14	14.3	
5 Plainfield fine sand	1.4	1.4				
6 Fresno sandy loam	3.1	3.1	3.1	3	3	
7 Tehama loam	4.5	4.5	4.4			
8 Placencia loam	5.8	6	6.1			
9 Wooster silt loam	6.2	6	5.8			
10 Madera & Gridley loam	10.5	10.5	10.4	10.5	10.4	
11 Brockton clay loam	11.6	11.4	11.6			

Part V: PERMANENT WILTING PERCENTAGE: END OF GROWING SEASON

Soil	Wilting Percentages at:									
	1	2	3	4	5	6	7	8	9	10
Depth ft	yr	yr	yr	yr	yr	yr	yr	yr	yr	yr
Peach (<i>Prunus persica</i>)										
10-3	9.9	8.0	8.7	8.8	8.6	9.2	10.5	10.3	9.8	9.7
23-6	8.6	8.0	8.4	7.8	8.0	8.3	9.4	9.6	9.1	8.6
36-9	7.9	7.4	7.6	7.7	7.6	7.6	9.1	8.8	7.7	7.4
49-12	8.8	7.4	8.3	8.3	7.7					
Plum (<i>Prunus americana</i>)										
50-3	8.4	9.0	8.7	8.5	8.5	8.4	8.8	8.9	8.8	8.9
63-6	7.9	7.8	8.0	7.8	8.0	8.2	8.6	7.8	7.6	8.4
76-9	9.8	10.2	9.7	9.9	10.0	9.7	10.3	9.6	10.6	
Walnut (<i>Juglans sp</i>)										
80-3	10.5	10.8	11.0	11.1	10.1	10.8	11.3	11.0	10.4	11.1
93-6	11.3	11.2	11.1	10.5	10.7	11.1	11.2	11.1	10.9	11.4
106-9	8.4	8.9	9.1	8.7	7.9	8.7	8.8	9.0	9.5	9.5

382. SOIL pH ADAPTATIONS: PLANTS

Plant growth is best at the pH indicated and only fair at the limits of the ranges shown in parentheses - estimates "c" of the 95% range (cf Introduction).

Species		Soil pH	Species		Soil pH
Field and Forage Crops			Ornamental Plants (concluded)		
1	Alfalfa (<i>Medicago sativa</i>)	6.0-7.5(5.5-8.5)	76	Primrose, evening (<i>Oenothera biennis</i>)	6.0-8.0
2	Barley (<i>Hordeum vulgare</i>)	6.0-7.5(5.5-8.5)	77	Rose (<i>Rosa hybrida</i>)	5.5-7.0(5.0-7.5)
3	Beet, sugar (<i>Beta vulgaris</i>)	6.5-8.0(5.5-8.5)	78	Snapdragon (<i>Antirrhinum majus</i>)	6.0-7.5(5.0-8.0)
4	Bluegrass, Kentucky (<i>Poa pratensis</i>)	5.5-7.5	79	Spiderwort (<i>Tradescantia virginiana</i>)	5.0-7.5
5	Buckwheat (<i>Fagopyrum esculentum</i>)	5.5-7.0(4.5-8.0)	80	Stock (<i>Matthiola incana</i>)	6.0-7.5
6	Clover, red (<i>Trifolium pratense</i>)	6.0-7.5	81	Tulip (<i>Tulipa gesneriana</i>)	6.0-7.5
7	Clover, white (<i>T. repens</i>)	6.0-7.5	Trees and Shrubs		
8	Cotton (<i>Gossypium hirsutum</i>)	5.0-6.5(to 8.5)	82	Acacia (<i>Acacia</i> spp)	6.5-8.0
9	Flax (<i>Linum usitatissimum</i>)	5.0-7.0(to 8.5)	83	Ailanthus (<i>Ailanthus altissima</i>)	6.0-8.0
10	Hemp (<i>Cannabis sativa</i>)	6.0-7.5	84	Alder (<i>Alnus</i> spp)	6.0-7.5
11	Oat (<i>Avena sativa</i>)	5.0-7.5(4.5-8.0)	85	Aspen, quaking (<i>Populus tremuloides</i>)	4.0-5.5
12	Peanut (<i>Arachis hypogaea</i>)	5.0-6.5(to 8.0)	86	Baldcypress (<i>Taxodium distichum</i>)	6.0-7.5
13	Redtop (<i>Agrostis alba</i>)	5.0-6.5	87	Basswood (<i>Tilia</i> spp)	6.0-7.5
14	Rice (<i>Oryza sativa</i>)	5.0-6.5	88	Beech, European (<i>Fagus sylvatica</i>)	6.0-7.5
15	Rye (<i>Secale cereale</i>)	5.0-7.0(4.5-8.0)	89	Beech, American (<i>F. grandifolia</i>)	5.0-6.5
16	Sorghum (<i>Sorghum vulgare</i>)	5.5-7.5(4.5-8.0)	90	Birch, sweet (<i>Betula lenta</i>)	4.5-6.0
17	Soybean (<i>Glycine soja</i>)	6.0-7.5	91	Buckeye, Ohio (<i>Aesculus glabra</i>)	6.0-7.5
18	Sugar cane (<i>Saccharum officinarum</i>)	6.0-8.0(5.0-)	92	Buckeye, red (<i>A. pavia</i>)	5.0-6.5
19	Sunflower (<i>Helianthus annuus</i>)	6.0-7.5	93	Catalpa (<i>Catalpa</i> spp)	6.0-7.5
20	Sweetclover (<i>Melilotus alba</i>)	6.5-8.0	94	Cherry, choke (<i>Prunus virginiana</i>)	6.0-7.5
21	Tobacco (<i>Nicotiana tabacum</i>)	5.5-7.5(4.5-)	95	Chestnut, American (<i>Castanea dentata</i>)	4.0-6.5
22	Wheat (<i>Triticum aestivum</i>)	5.5-7.5(5.0-8.5)	96	Chinkapin, Allegheny (<i>C. pumila</i>)	4.0-6.5
Fruit and Vegetable Crops			97	Dogwood, flowering (<i>Cornus florida</i>)	5.0-6.5
23	Apple (<i>Pyrus malus</i>)	5.0-6.5(to 8.0)	98	Douglas-fir (<i>Pseudotsuga taxifolia</i>)	5.0-6.5
24	Bean, lima (<i>Phaseolus lunatus macrocarpus</i>)	6.0-7.5	99	Elm (<i>Ulmus</i> spp) ¹	6.0-8.0
25	Bean, string (<i>P. vulgaris</i>)	6.0-7.5	100	Eucalyptus (<i>Eucalyptus</i> spp)	6.5-8.0
26	Beet, garden (<i>Beta vulgaris</i>)	6.0-7.5	101	Fir (<i>Abies</i> spp)	4.0-6.5
27	Blueberry (<i>Vaccinium</i> spp)	4.5-6.0	102	Ginkgo (<i>Ginkgo biloba</i>)	5.5-7.0
28	Cabbage (<i>Brassica oleracea capitata</i>)	6.0-7.5(to 8.5)	103	Hackberry (<i>Celtis</i> spp)	6.0-7.5
29	Cantaloupe (<i>Cucumis melo</i>)	6.0-8.0	104	Hemlock, eastern (<i>Tsuga canadensis</i>)	4.5-6.0
30	Carrot (<i>Daucus carota</i>)	5.5-7.0(5.0-8.5)	105	Hickory, shagbark (<i>Carya ovata</i>)	6.0-6.5
31	Celery (<i>Apium graveolens dulce</i>)	6.0-7.5(to 8.5)	106	Holly, American (<i>Ilex opaca</i>)	4.5-6.0
32	Corn (<i>Zea mays</i>)	5.5-7.5(5.0-8.0)	107	Holly, English (<i>I. aquifolium</i>)	5.0-6.5
33	Cucumber (<i>Cucumis sativus</i>)	5.5-7.0(to 8.0)	108	Honeylocust (<i>Gleditsia triacanthos</i>)	6.0-7.5
34	Lemon (<i>Citrus limonia</i>)	6.0-7.5(to 8.5)	109	Hophornbeam, eastern (<i>Ostrya virginiana</i>)	6.0-7.0
35	Lettuce (<i>Lactuca sativa</i>)	6.0-7.5(5.5-8.0)	110	Hornbeam (<i>Carpinus</i> spp)	6.0-7.5
36	Onion (<i>Allium cepa</i>)	6.0-7.5(5.0)	111	Horsechestnut (<i>Aesculus hippocastanum</i>)	5.5-7.0
37	Orange, sweet (<i>Citrus sinensis</i>)	6.0-7.5	112	Juniper (<i>Juniperus</i> spp)	5.5-7.5
38	Parsley (<i>Petroselinum hortense</i>)	5.0-7.0	113	Juniper, common (<i>J. communis</i>)	5.0-6.5
39	Pea, garden (<i>Pisum sativum</i>)	6.0-8.0	114	Juniper, mountain (<i>J. communis saxatilis</i>)	4.0-5.5
40	Peach (<i>Prunus persica</i>)	6.0-7.5	115	Coffeetree, Kentucky (<i>Gymnocladus dioica</i>)	6.0-7.5
41	Pear (<i>Pyrus communis</i>)	6.0-7.5	116	Larch (<i>Larix</i> spp)	4.5-7.5
42	Pepper (<i>Capsicum annum</i>)	5.5-7.0	117	Locust (<i>Robinia</i> spp)	5.5-7.5
43	Pineapple (<i>Ananas sativus</i>)	5.0-6.5	118	Magnolia, southern (<i>Magnolia grandiflora</i>)	5.0-7.0
44	Potato (<i>Solanum tuberosum</i>)	5.0-6.5(7.0-8.0)	119	Maple (<i>Acer</i> spp)	5.5-7.5
45	Radish (<i>Raphanus sativus</i>)	5.5-7.0(5.0-8.0)	120	Maple, mountain (<i>A. spicatum</i>)	4.5-6.0
46	Spinach (<i>Spinacia oleracea</i>)	6.0-7.5(5.5-8.5)	121	Mountain-ash, American (<i>Sorbus americana</i>)	4.5-6.5
47	Squash, winter (<i>Cucurbita maxima</i>)	5.5-7.0	122	Mountain-ash, European (<i>S. aucuparia</i>)	5.5-7.5
48	Strawberry (<i>Fragaria</i> spp)	5.0-6.5(4.5-8.0)	123	Mountain-laurel (<i>Kalmia latifolia</i>)	4.0-6.0
49	Sweetpotato (<i>Ipomoea batatas</i>)	5.0-6.5(to 7.5)	124	Mulberry (<i>Morus</i> spp)	6.0-7.5
50	Tomato (<i>Lycopersicon esculentum</i>)	5.5-7.5(4.5-)	125	Oak (<i>Quercus</i> spp) ²	4.5-6.5
51	Turnip (<i>Brassica napus</i>)	5.5-7.0	126	Oak (<i>Quercus</i> spp) ³	4.0-5.0
52	Watermelon (<i>Citrullus vulgaris</i>)	5.0-6.5(5.0-8.0)	127	Oak, English (<i>Q. robur</i>)	6.0-7.5
Ornamental Plants			128	Oak, white (<i>Q. alba</i>)	6.5-7.5
53	African-violet (<i>Saintpaulia ionantha</i>)	5.5-7.0	129	Oak, willow (<i>Q. phellos</i>)	4.5-6.5
54	Almond, flowering (<i>Prunus glandulosa</i>)	6.0-7.5	130	Paulownia, royal (<i>Paulownia tomentosa</i>)	5.5-7.5
55	Aster, China (<i>Callistephus chinensis</i>)	6.0-7.5(5.5-)	131	Pine (<i>Pinus</i> spp)	4.0-6.5
56	Balsam, garden (<i>Impatiens balsamina</i>)	6.0-7.5(5.5-)	132	Pine, longleaf (<i>P. palustris</i>)	4.0-6.0
57	Begonia (<i>Begonia</i> spp)	5.5-7.0	133	Pine, red (<i>P. resinosa</i>)	5.0-6.0
58	Boxwood (<i>Buxus sempervirens</i>)	6.0-7.5	134	Poplar (<i>Populus</i> spp)	5.5-7.5
59	Camellia (<i>Camellia japonica</i>)	4.5-6.0	135	Redbud, eastern (<i>Cercis canadensis</i>)	6.0-7.5
60	Canna (<i>Canna indica</i>)	6.0-8.0	136	Redcedar, eastern (<i>Juniperus virginiana</i>)	5.0-8.0
61	Carnation (<i>Dianthus caryophyllus</i>)	6.0-7.5(5.0-)	137	Rhododendron (<i>Rhododendron</i> spp)	4.0-6.0
62	Chrysanthemum (<i>Chrysanthemum morifolium</i>)	6.0-7.5(5.0-8.0)	138	Service berry (<i>Amelanchier</i> spp)	5.0-7.5
63	Coleus (<i>Coleus blumei</i>)	6.0-7.5	139	Spruce (<i>Picea</i> spp)	4.0-6.5
64	Dahlia (<i>Dahlia</i> spp)	6.0-8.0	140	Spruce, blue (<i>P. pungens</i>)	5.0-6.5
65	Gardenia (<i>Gardenia jasminoides</i>)	5.0-7.0	141	Spruce, Sitka (<i>P. sitchensis</i>)	5.0-6.5
66	Geranium (<i>Pelargonium domesticum</i>)	6.0-8.0(5.0-)	142	Sweetgum (<i>Liquidambar styraciflua</i>)	5.0-6.5
67	Gladiolus (<i>Gladiolus</i> spp)	6.0-8.0	143	Sycamore (<i>Platanus</i> spp)	5.5-7.5
68	Hibiscus, Chinese (<i>Hibiscus rosa-sinensis</i>)	6.0-8.0	144	Tupelo, black (<i>Nyssa sylvatica</i>)	4.5-6.0
69	Hyacinth (<i>Hyacinthus orientalis</i>)	6.0-7.5	145	Walnut (<i>Juglans</i> spp)	6.0-7.5
70	Iris, bearded (<i>Iris</i> spp)	6.0-8.0	146	White-cedar, Atlantic (<i>Chamaecyparis thyoides</i>)	4.0-6.0
71	Ivy, English (<i>Hedera helix</i>)	6.0-8.0	147	White-cedar, northern (<i>Thuja occidentalis</i>)	6.0-7.5(5.5-8.5)
72	Kalanchoe (<i>Kalanchoe blossfeldiana</i>)	6.0-7.5	148	Willow (<i>Salix</i> spp)	5.5-7.5
73	Lily, Easter (<i>Lilium longiflorum</i>)	6.0-7.5	149	Willow, creeping (<i>S. repens</i>)	4.5-6.0
74	Nasturtium (<i>Tropaeolum majus</i>)	5.5-7.5	150	Yellow-poplar (<i>Liriodendron tulipifera</i>)	5.5-7.5
75	Narcissus (<i>Narcissus</i> spp)	5.0-7.0	151	Yew (<i>Taxus</i> spp)	5.0-7.5

/1/ Species include: American elm (*U. americana*), Chinese elm (*U. parvifolia*). /2/ Species include: black oak (*Q. velutina*), northern red oak (*Q. rubra*), scarlet oak (*Q. coccinea*). /3/ Species include: blackjack oak (*Q. marilandica*), post oak (*Q. stellata*), turkey oak (*Q. laevis*), southern red oak (*Q. falcata*). For pin oak (*Q. palustris*) and chestnut oak (*Q. prinus*), 6.0-7.0.

383. BORON TOLERANCE: PLANTS

For each tolerance group, plants are listed in order of decreasing tolerance to boron present in nutrient solutions. Differences of a few places in position may not be significant, and there is no sharp division between successive groups. Boron concentrations indicate the range within which injury was observed at the time of harvest.

High Tolerance (Boron 25-10 ppm)			Median Tolerance (Boron 10-5 ppm) (concluded)			Low Tolerance (5-1 ppm) (concluded)		
1	Athel (Tamarix aphylla)	18	Cotton, Acala (Gossypium hirsutum)	36	Walnut (Juglans nigra)	43	Apple (P. malus)	51
2	Asparagus (Asparagus officinalis)	19	Cotton, Pima (G. barbadense)	37	Walnut (J. regia)	44	Grape, Malaga and Sultanina (Vitis vinifera)	52
3	Palm (Phoenix canariensis)	20	Tomato (Lycopersicon esculentum)	38	Artichoke (Helianthus tuberosus)	45	Fig, Kadota (Ficus carica)	53
4	Date (P. dactylifera)	21	Sweet pea (Lathyrus odoratus)	39	Bean, navy (Phaseolus vulgaris)	46	Persimmon (Diospyros virginiana)	54
5	Beet, sugar (Beta vulgaris)	22	Radish (Raphanus sativus)	40	Elm (Ulmus americana)	47	Cherry (Prunus spp)	
6	Beet, mangel (B. vulgaris)	23	Pea, field (Pisum sp)	41	Plum (Prunus sp)	48	Peach (P. persica)	
7	Beet, garden (B. vulgaris)	24	Olive (Oleo europaea)	42	Pear (Pyrus communis)	49	Apricot (P. armeniaca)	
8	Alfalfa (Medicago sativa)	25	Barley (Hordeum vulgare)	43	Apple (P. malus)	50	Blackberry, thornless (Rubus sp)	
9	Gladiolus (Gladiolus spp)	26	Wheat (Triticum aestivum)	44	Grape, Malaga and Sultanina (Vitis vinifera)	51	Orange (Citrus spp)	
10	Broadbean (Vicia faba)	27	Corn (Zea mays)	45	Fig, Kadota (Ficus carica)	52	Avocado (Persea gratissima)	
11	Onion (Allium cepa)	28	Milo (Sorghum vulgare)	46	Persimmon (Diospyros virginiana)	53	Grapefruit (Citrus paradisi)	
12	Turnip (Brassica rapa)	29	Oat (Avena sativa)	47	Cherry (Prunus spp)	54	Lemon (C. limonia)	
13	Cabbage (B. oleraceae cap.)	30	Zinnia (Zinnia sp)	48	Peach (P. persica)			
14	Lettuce (Lactuca sativa)	31	Pumpkin (Cucurbita pepo)	49	Apricot (P. armeniaca)			
15	Carrot (Daucus carota)	32	Pepper, bell (Capsicum sp)	50	Blackberry, thornless (Rubus sp)			
Medium Tolerance (Boron 10-5 ppm)			33	Sweetpotato (Ipomoea batatas)	51	Orange (Citrus spp)		
16	Sunflower (Helianthus annuus)	34	Bean (Phaseolus lunatus mac.)	52	Avocado (Persea gratissima)			
17	Potato (Solanum tuberosum)	35	Pecan (Carya illinoensis)	53	Grapefruit (Citrus paradisi)			

384. SALT TOLERANCE: PLANTS

Salinity values are expressed in terms of electrical conductivity (EC_e) of the saturation extract of active root-zone soil, and are for total soluble salts. Units of conductivity measurement are millimhos per cm at 25°C. In each tolerance group, plants are listed in order of decreasing salt tolerance; however, individual differences from one place to the next may not be significant.

Part I: EFFECT ON CROP YIELD

Data correlate soil salinity with crop yield. Plants listed at the beginning and at the end of each tolerance group may be expected to produce only 50% of a normal yield when grown in soils of salinity represented in upper and lower ranges.

Fruit Crops			Vegetable Crops (concluded)			Forage Crops (concluded)		
High Tolerance			Medium Tolerance ($EC_e \times 1000 = 10-4$) (concl'd)			High Tolerance ($EC_e \times 1000 = 18-12$) (concluded)		
1	Date (Phoenix dactylifera)	30	Squash (Cucurbita spp)	57	Wheatgrass (Agropyron smithii)	58	Barley (Hordeum vulgare) ²	
Medium Tolerance			31	Cucumber (Cucumis sativus)	59	Trefoil (Lotus corniculatus)		
2	Pomegranate (Punica granatum)		Low Tolerance ($EC_e \times 1000 = 4-3$)			Medium Tolerance ($EC_e \times 1000 = 12-4$)		
3	Fig (Ficus carica)	32	Radish (Raphanus sativus)	60	Sweetclover (Melilotus alba)	61	Sweetclover (M. officinalis)	
4	Olive (Olea europaea)	33	Celery (Apium graveolens)	62	Sweetclover (M. officinalis)	63	Ryegrass (Lolium perenne)	
5	Grape (Vitis vinifera)	34	Bean, garden (Phaseolus vulgaris)	64	Brome (Bromus marginatus)	65	Clover (Trifolium fragiferum)	
6	Cantaloupe (Cucumis melo cant.)		Field Crops			66	Dallis grass (Paspalum dilatatum)	
Low Tolerance			35	High Tolerance ($EC_e \times 1000 = 16-10$)			67	Sudan grass (Sorghum sudanense)
7	Pear (Pyrus communis)	36	Barley (Hordeum vulgare) ¹	68	Sweetclover, hubam (Melilotus alba)	69	Alfalfa (Medicago sativa)	
8	Apple (P. malus)	37	Beet, sugar (Beta vulgaris)	70	Fescue (Festuca elatior arundinacea)	71	Rye (Secale cereale) ²	
9	Prune (Prunus sp)	38	Rape (Brassica napus)	72	Wheat (Triticum aestivum) ²	73	Oat (Avena sativa) ²	
10	Plum (P. americana)	39	Cotton (Gossypium sp)	74	Orchard grass (Dactylis glomerata)	75	Bluegrama (Bouteloua gracilis)	
			Medium Tolerance ($EC_e \times 1000 = 10-6$)			76	Fescue (Festuca elatior)	
11	Almond (Amygdalus communis)	40	Rye (Secale cereale) ¹	77	Canary grass (Phalaris arundinacea)	78	Trefoil (Lotus uliginosus)	
12	Apricot (Prunus armeniaca)	41	Wheat (Triticum aestivum) ¹	79	Brome (Bromus inermis)	80	Oatgrass (Arrhenatherum elatius)	
13	Peach (P. persica)	42	Oat (Avena sativa) ¹	81	Milk vetch (Astragalus cicer)	82	Sourclover (Melilotus indica)	
14	Strawberry (Fragaria sp)	43	Rice (Oryza sativa)	83	Milk vetch (Astragalus falcatus)			
Vegetable Crops			44	Low Tolerance ($EC_e \times 1000 = 4$)				
High Tolerance ($EC_e \times 1000 = 12-10$)			45	Forage Crops <td></td> <td></td>				
15	Beet, garden (Beta vulgaris)	46	Sorghum (Sorghum vulgare) ¹		High Tolerance ($EC_e \times 1000 = 18-12$)			
16	Kale (Brassica oleracea acephala)	47	Corn (Zea mays)	49	Sacaton (Sporobolus airoides)			
17	Asparagus (Asparagus officinalis)	48	Flax (Linum usitatissimum)	50	Saltgrass (Distichlis stricta)			
18	Spinach (Spinacia oleracea)	49	Sunflower (Helianthus annuus)	51	Nuttall alkali grass (Puccinellia nuttallians)			
Medium Tolerance ($EC_e \times 1000 = 10-4$)			52	Bermuda grass (Cynodon dactylon)	84	Whiteclover (Trifolium repens)	85	Foxtail (Alopecurus pratensis)
19	Tomato (Lycopersicon esculentum)	53	Castor bean (Ricinus communis)	54	Rhodes grass (Chloris gayana)	86	Clover (Trifolium hybridum)	
20	Broccoli (Brassica oleracea italica)	54	Low Tolerance ($EC_e \times 1000 = 4$)			87	Clover (T. pratense)	
21	Cabbage (B. oleracea capitata)	55	Bean, field (Phaseolus sp)	56	Wild rye (Elymus canadensis)	88	Clover, Ladino (T. repens)	
22	Pepper, bell (Capsicum sp)		Forage Crops			89	Burnet (Sanguisorba minor)	
23	Cauliflower (Brassica oleracea bot.)			High Tolerance ($EC_e \times 1000 = 18-12$)				
24	Lettuce (Lactuca sativa)		49	Sacaton (Sporobolus airoides)				
25	Corn, sweet (Zea mays)		50	Saltgrass (Distichlis stricta)				
26	Potato (Solanum tuberosum)		51	Nuttall alkali grass (Puccinellia nuttallians)				
27	Carrot (Daucus carota)		52	Bermuda grass (Cynodon dactylon)				
28	Onion (Allium cepa)		53	Rhodes grass (Chloris gayana)				
29	Pea (Pisum sativum)		54	Rescue grass (Bromus catharticus)				
			55	Wild rye (Elymus canadensis)				
			56	Wild rye (E. triticoides)				

/1/ Tolerance determined on basis of yield of grain. /2/ Determined as yield in hay.

Part II: EFFECT ON PLANT

Data are based on soil salinity values at which no evidence of toxicity is generally observed. For citrus and avocados the salts present in the soil were predominantly chlorides; for other plants, a mixture of chlorides and sulfates.

Medium Tolerance ($EC_e \times 1000 = 8-4$)			Poor Tolerance ($EC_e \times 1000 = 4-2$) (concluded)			Very Poor Tolerance ($EC_e \times 1000 = 2-1$) (concluded)		
	Grapefruit (Citrus paradisi)			Grapefruit (Citrus paradisi) (concluded)		17	Avocado, Mexican	
1	on Rangpur lime	8		on Sampson tangelo			on West Indian	
	Orange (Citrus spp)	9		on sweet orange			Grapefruit (Citrus Paradisi)	
2	on Cleopatra mandarin			Lemon (C. limonia)		18	on trifoliolate-orange	
	Grapefruit (C. paradisi)	10		on sour orange		19	on Troyer citrange	
3	on Cleopatra mandarin	11		Plum, Natal (Prunus americana)		20	on Kara mandarin	
4	on Timkat mandarin			Avocado, West Indian (Persea gratissima)		21	on king orange	
	Poor Tolerance ($EC_e \times 1000 = 4-2$)	12		on West Indian		22	Sapote, white	
	Orange (Citrus spp)	13		Cherry, Surinam (Prunus sp)		23	Mango, Saigon (Mangifera indica)	
5	on sour lime	14		Cherry, haden (Prunus sp)		24	Mango, Brooks (M. indica)	
	Grapefruit (C. paradisi)			Very Poor Tolerance ($EC_e \times 1000 = 2-1$)			Avocado, Mexican (Persea gratissima)	
6	on rough lemon	15		Papaya (Carya papaya)		25	on Mexican	
7	on sour orange			Avocado, Lula (Persea gratissima)		26	Cherimoya (Annona cherimola)	
		16		on West Indian				

385. SALINITY TOLERANCES: AQUATIC ANIMALS

Data are based on field observations unless otherwise indicated in footnotes. Tolerance to salinity alone is often not the most critical factor, as it differs with the age of the individual, temperature and hydrogen ion concentration of the water, previous conditioning, length of exposure, and other variables. Values represent lower and upper limits of salinity at which these animals have been found to survive. Salinity is defined as the total weight of dissolved solids in 1 kg of water at 27°C (80.6°F), expressed as g/kg or o/oo.

FW = fresh water; BW = brackish water; MW = marine water; SLW = highly saline lake water.

Animal	Normal Habitat ¹	Salinity Tolerance g/kg or o/oo	Animal	Normal Habitat ¹	Salinity Tolerance g/kg or o/oo
Porifera			Teleostomi (concluded)		
1 Sponge, boring or sulfur (<i>Cliona celata</i>)	MW	15-36	58 Flounder, fringed (<i>Etropus crossotus</i>)	MW	4.4-37
Coelenterata			59 Flounder, gulf (<i>Paralichthys lethostigma</i>)	MW, BW ¹³	0-36
2 Hydra (<i>Chlorohydra</i> and <i>Pelmatohydra</i>)	FW	0-2.5	60 Flounder, Gunter's (<i>Syacium gunteri</i>)	MW	31-35
3 Hydroid (<i>Clava</i>)	BW	10-30	61 Gaff-topsail (<i>Bagre marina</i>)	MW, BW ¹³	0-34
4 Moon jelly (<i>Aurelia aurita</i>)	MW	16-35	62 Gar, alligator (<i>Lepisosteus spatula</i>)	BW	0-31
5 Sea nettle (<i>Dactylometra quinquecirrha</i>)	MW	16-35	63 Goby, darting (<i>Gobionellus boleosoma</i>)	MW	15-30
6 Sea pansy (<i>Renilla muelleri</i>)	MW	27-37	64 Goby, naked (<i>Gobiosoma bosci</i>) ¹³	BW	0-20
Turbellaria			65 Goldfish (<i>Carassius auratus</i>)	FW	0-15
7 Flatworm (<i>Procerodes littoralis</i>)	BW	3.5-35 ²	66 Green chromide (<i>Etropus suratensis</i>)	BW	0-35
Annelida			67 Grouper, high-finned (<i>Cromileptes altivelis</i>)	MW ¹³	0-35
8 Clamworm (<i>Nereis diversicolor</i>)	BW	4-32 ³	68 Hake, southern (<i>Urophycis floridanus</i>)	MW	13-34
Mollusca			69 Jack (<i>Caranx ignobilis</i>)	MW ¹³	0-35
9 Octopus (<i>Octopus vulgaris</i>)	MW	30-35	70 Jack (<i>C. sexfasciatus</i>)	MW ¹³	0-35
10 Oyster, eastern (<i>Crassostrea virginica</i>)	MW, BW	7-27 ⁴	71 Jack, common (<i>C. hippos</i>)	MW ¹³	0-36
11 Oyster, horse (<i>Ostrea equestris</i>)	MW	27-35	72 Jarbua (<i>Therapon jarbua</i>)	MW, BW	0-35
12 Squid, common (<i>Loligo pealii</i>)	MW	31-36	73 Killifish, California (<i>Fundulus parvipinnis</i>)	MW ¹⁵	0-35 ¹⁶
13 Squid, short (<i>Lolligunculus brevis</i>)	MW	18-37	74 Killifish, gulf (<i>F. grandis</i> and <i>F. similis</i>)	BW	2-37 ¹⁶
14 Tun, giant (<i>Tonna galea</i>)	MW	30-38	75 Killifish, mummichog (<i>F. heteroclitus</i>)	MW ¹⁷	0-35 ¹⁶
15 Wheelk, lightning (<i>Busyon contrarium</i>)	MW	20-37	76 Langaray (<i>Ambassis lala</i>)	MW, BW, FW	0-35
Crustacea			77 Menhaden (<i>Brevoortia smithi</i>)	BW	2-34
16 Crab (<i>Heloeius cordiformis</i>)	BW, MW	0.7-53	78 Milkfish (<i>Chanos chanos</i>)	MW	0-35
17 Crab, blue (<i>Callinectes sapidus</i>) ⁵	BW, MW	0-37	79 Minnow, variegated (<i>Cyprinodon variegatus</i>)	BW ¹³	0-71
18 Crab, gulf (<i>C. danae</i>)	MW	17-37	80 Mojarra (<i>Eucinostomus argenteus</i>)	MW ¹³	0-37
19 Crab, mitten (<i>Eriocheir sinensis</i>) ⁶	FW, BW, MW	0-47	81 Moonfish (<i>Vomer setapinnis</i>)	MW	17-37
20 Crab, stone (<i>Menippe mercenaria</i>) ⁷	BW, MW	12-34	82 Mouthbreeder (<i>Tilapia mossambica</i>)	FW ¹⁸	0-69
21 Sea bob (<i>Xiphopenus kryeri</i>)	MW	22-36	83 Mudskipper (<i>Periophthalmus barbarus</i>)	BW	0-35
22 Shrimp (<i>Crango franciscorum</i>)	MW	12-35	84 Mullet, striped (<i>Mugil cephalus</i>)	MW, BW ¹³	0-35 ¹⁶
23 Shrimp (<i>Palaemon longirostris</i>)	MW	0-35	85 Needlefish (<i>Strongylura marina</i>)	MW, BW ¹³	0-37
24 Shrimp, brine (<i>Artemia salina</i>)	SLW	<35-220 ⁸	86 Paradise fish (<i>Macropodus opercularis</i>)	FW	0-30
25 Shrimp, grass (<i>Palaemonetes vulgaris</i>) ⁹	BW, MW	2-34	87 Pigfish (<i>Orthopristis chrysopterus</i>)	MW	10-37
26 Shrimp, white (<i>Peneus setiferus</i>) ¹⁰	BW, MW	0.8-35	88 Pinfish (<i>Lagodon rhomboides</i>)	MW, BW ¹³	0-37
Echinodermata			89 Pipefish (<i>Syngnathus scovelli</i>)	BW	0-26
27 Sand dollar (<i>Mellita quinqueperforata</i>)	MW	30-35	90 Pompano, common (<i>Trachinotus carolinus</i>)	MW	28-37
28 Star, brittle or serpent (<i>Amphiodia limbata</i>) ¹¹	BW, MW	8.9-36	91 Rain-water fish (<i>Lucania para venusta</i>)	BW ¹³	0-24
Elasmobranchii¹²			92 Sailfin molly (<i>Mollienesia latipinna</i>)	FW, BW ¹³	0-87
29 Sawfish, Pacific (<i>Pristis microdon</i>)	MW ¹³	0-35	93 Salmon, chum (<i>Oncorhynchus keta</i> , fry)	FW	0-30
30 Shark, blacknose (<i>Carcharhinus limbatus</i>)	MW	11-35	94 Salmon, king (<i>O. tshawytscha</i>)	FW, MW	0-35
31 Shark, bonnethead (<i>Sphyrna tiburo</i>)	MW	23-36	95 Salmon, silver (<i>O. kisutch</i>), fry	FW	0-15
32 Shark, Ganges (<i>Carcharhinus gangeticus</i>)	MW ¹³	0-35	96 Sardine, silver (<i>Harengula pensacola</i>)	BW	4.8-37
33 Stingray (<i>Dasyatis americana</i>)	MW	29-36	97 Scatfish (<i>Scatophagus argus</i>)	MW, BW, FW	0-35
34 Stingray (<i>D. sabina</i>)	MW ¹³	0-37	98 Scatfish (<i>Selenotoca papuensis</i>)	MW, BW	0-35
35 Torpedo fish (<i>Narcine brasiliensis</i>)	MW	31-37	99 Sea perch, silver (<i>Lates calcarifer</i>)	MW	0-35
Teleostomi¹⁴			100 Sea robin (<i>Prionotus tribulus</i>)	MW	10-37
36 Anchovy (<i>Anchoa hepsetus</i>)	BW	2.5-37	101 Shad, gizzard (<i>Dorosoma cepedianum</i>)	BW	0-34
37 Anchovy, bay (<i>A. mitchilli diaphana</i>)	BW ¹³	0-37	102 Sheephead (<i>Archosargus probatocephalus</i>)	BW	2.2-30
38 Archerfish (<i>Toxotes jaculator</i>)	MW, BW, FW	0-35	103 Silverside, common (<i>Menidia beryllina</i>)	BW ¹³	0 to >80
39 Bararog (<i>Leiognathus caballus</i>)	MW	0-35	104 Sleeper, striped (<i>Dormitorator maculatus</i>)	BW ¹³	0-35
40 Barb (<i>Puntius javanicus</i>)	FW	0-8	105 Snapper (<i>Lutianus argentiventris</i>)	MW ¹³	0-35
41 Bass, mountain (<i>Kuhlia sandvicensis</i>)	MW, BW ¹³	0-35	106 Sole, broad (<i>Trinectes fasciatus</i>)	MW, BW ¹³	0-34
42 Batfish, silver (<i>Monodactylus argenteus</i>)	MW, BW	0-35	107 Sole, lined (<i>Achirus lineatus</i>)	MW	2.5-36
43 Blowfish (<i>Sphoeroides marmoratus</i>)	MW	4.4-36	108 Spadefish (<i>Chaetodipterus faber</i>)	MW	11-36
44 Bumper (<i>Chloroscombrus chrysurus</i>)	MW	17-37	109 Squeteague, sand (<i>Cynoscion arenarius</i>)	BW	4.9-30
45 Carp (<i>Cyprinus carpio</i>)	FW	0-10	110 Squeteague, sand (<i>C. nothus</i>)	MW	18-37
46 Catfish, blue (<i>Ictalurus furcatus</i>)	FW	0-6.9	111 Squeteague, speckled (<i>C. nebulosus</i>)	BW ¹³	0-75
47 Catfish, sea (<i>Galeichthys felis</i>)	MW, BW ¹³	0-60	112 Stickleback, 3-spine (<i>Gasterosteus aculeatus</i>)	FW, MW	0-55
48 Croaker (<i>Micropogon undulatus</i>)	MW, BW	0-37	113 Tarpon (<i>Tarpon atlanticus</i>)	MW ¹³	0-35
49 Croaker, spot (<i>Leiostomus xanthurus</i>)	MW, BW ¹³	0-37	114 Tarpon, Asiatic (<i>Megalops cyprinoides</i>)	MW ¹³	0-35
50 Cutlassfish (<i>Trichiurus lepturus</i>)	MW	13-37	115 Tenpounder (<i>Elops saurus</i>)	MW, BW ¹³	0-35
51 Damselfish (<i>Pomacentrus fuscus</i>)	MW	0-35	116 Threadfin (<i>Polydactylus octonemus</i>)	BW	2.1-37
52 Drum, black (<i>Pogonias cromis</i>)	MW, BW	0-50	117 Tonguefish (<i>Symphurus plagiosa</i>)	MW	17-37
53 Drum, channel (<i>Sciaenops ocellata</i>)	MW, BW	0-32	118 Trout, steelhead (<i>Salmo gairdneri</i>)	FW, MW	0-35
54 Drum, star (<i>Stellifer lanceolatus</i>)	MW	8.9-37	119 Whiff (<i>Citharichthys spilopterus</i>)	BW ¹³	0-36.7
55 Eel, European (<i>Anguilla vulgaris</i>)	FW, MW	0-35	120 Whiting (<i>Menticirrhus americanus</i>)	MW	14-37
56 Faguito (<i>Limia vittata</i>)	FW, BW	0-35	121 Whiting, surf (<i>M. littoralis</i>)	MW	18-37
57 Flounder, European (<i>Pleuronectes flesus</i>)	MW	7-35	122 Yellowtail (<i>Bairdiella chrysura</i>)	BW	2.1-34

/1/ Brackish water species are usually euryhaline, i.e., able to live in waters of a wide range of salinity. Calcium ions aid fishes to withstand low salinities; field observations indicate that all marine animals invade fresh water of high Ca concentration much more than they do Ca-deficient fresh waters. /2/ Can undergo these changes with the tidal cycle. /3/ Has been adapted to chlorinities of about 0.25, and also observed in nearly fresh water in Denmark. /4/ Oysters withstand short-time salinity changes of 0-42 in the laboratory. /5/ May live in fresh water, but normal habitat is in estuarine waters of high salinity. /6/ Normally lives in fresh or brackish water, migrating to sea only to release larvae. /7/ Probably occurs more commonly in marine than brackish water. /8/ Occurs only in highly saline lakes; will tolerate sea water of <35 salinity (laboratory), but is not found in sea water of this salinity or other waters where there are predatory fish (Laguna Madre, Suez Canal). /9/ Recently split into 3 spp: *P. vulgaris*, *P. intermedius*, and *P. pugio*; it is possible that *P. vulgaris* does not occur in waters of low salinity. /10/ Only immature stages occur in brackish water. /11/ The common sea star (*Asterias forbesi*) can tolerate salinities down to 16 for short periods, and 18 regularly; *A. rubens* of Europe lives in a salinity of 18. /12/ Field observations; listed species where discovered in waters of known salinities; this constitutes a measure of tolerance, but does not indicate what are the physiological limits of tolerance to changes in salinity. /13/ Migrates into fresh water. /14/ Many marine teleosts can tolerate reduced salinity or fresh water if the change is not sudden. /15/ Abrupt transfer to fresh water causes 5-80% mortality. /16/ Salinity tolerance of 80-100 also reported. /17/ Gradual transfer to fresh water causes 11.5-56% mortality; abrupt transfer to fresh water causes 100% mortality. /18/ Will spawn in both fresh and salt water.

386. pH RANGE FOR GROWTH: REPRESENTATIVE MICROORGANISMS

Organism	Medium ¹	Temp °C	pH		Organism	Medium ¹	Temp °C	pH	
			Optimum	Range				Optimum	Range
1 Bacteria			6.5-7.5	3.8-12.0	20 Colpoda cucullus			6.5; 7.5	5.5-9.5
2 Molds			4.0-5.8	1.5-8.5	21 Didinium sp	S		6.4-8.4	5.2-9.4
3 Yeasts			3.8-6.0	2.5-8.0	22 Gastrostyla sp				6.0-8.5
4 Protozoa ²					23 Glaucoma scintillans	B		5.6-6.8	
Flagellates					24 Holophrya sp				6.5-7.4
5 Astasia klebsii	P	25	4.2-6.0	3.2-8.2	25 Paramecium aurelia	HF	25	7.0	5.7-7.8
6 A. longa	TR	25	6.0	3.3-9.6	26 P. bursaria	MS + P	19-26	6.7-6.8	4.9-8.0
7 Chloromonas paramecium	P	28	4.8-5.1	4.1-8.4	27 P. calkinsi	L		7.1-7.4	6.5-7.8
8 Chlorogonium elongatum	P	28	7.8	4.9-8.7	28 P. caudatum	HT	24	6.9-7.1	6.0-9.5
9 C. euchlorum	P	28	7.4	4.8-8.7	29 P. multimicronucleatum	HT	27	7.0	4.8-8.3
10 C. tetragonum	T + MS	28	8.6	4.2-8.8	30 P. polycaryum	LT		6.9-7.3	5.0-7.5
11 Euglena anabaena	P	29.5	6.9	4.5-8.3	31 P. trichium	HT		6.7-7.1	6.2-7.1
12 E. deses	P	29.5	7.0	5.3-8.0	32 P. woodruffi	L		7.0-7.5	6.5-7.5
13 E. gracilis	P	28.3	6.6	3.9-9.9	33 Plagiopyla sp				6.9-7.5
14 E. klebsii	P		6.5	5.5-7.5	34 Spirostomum ambiguum			7.4	6.8-7.5
15 E. mutabilis	P		3.4-5.4	2.1-7.7	35 Stentor coeruleus	MP	18-20	7.7-8.0	
16 E. pisciformis	P			6.0-8.0	36 Stylonychia pustulata	HT	25	6.7; 8.0	6.0-8.0
17 E. stellata	P		5.5	4.5-8.0	37 Tetrahymena pyriformis E	T	25	5.5; 7.4	4.5-8.5
18 Polytomella caeca	MS			4.0-7.2	38 T. pyriformis Gf-J	T	28	5.1-6.0	4.9-9.5
19 Ciliates	P			2.2-9.2	39 T. pyriformis GL	T	28	4.8-5.3	4.0-8.9
Amphileptus sp			7.1-7.3		40 T. pyriformis T-P	PH	24	7.0; 9.0	
					41 T. vorax D	P		6.2-7.6	

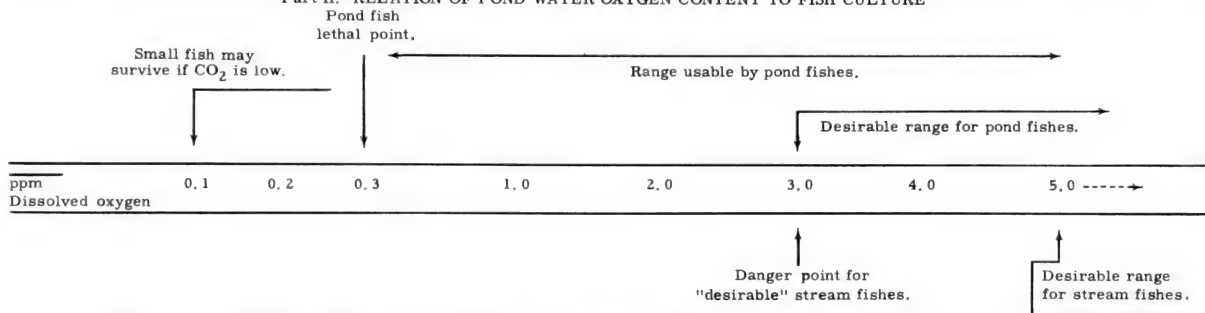
/1/ ¹ A = acetate; B = brewers yeast-Harris; HF = hay + flour; HT = hay tea; L = lettuce-sea water; LT = lettuce tea; MP = modified peters + ciliates; MS = mineral salts; P = peptone; PH = Phelps; S = spring water + paramecium; T = tryptone; TR = tryptophan. /2/ Exclusive of all parasitic forms.

387. FACTORS AFFECTING POND FISH CULTURE

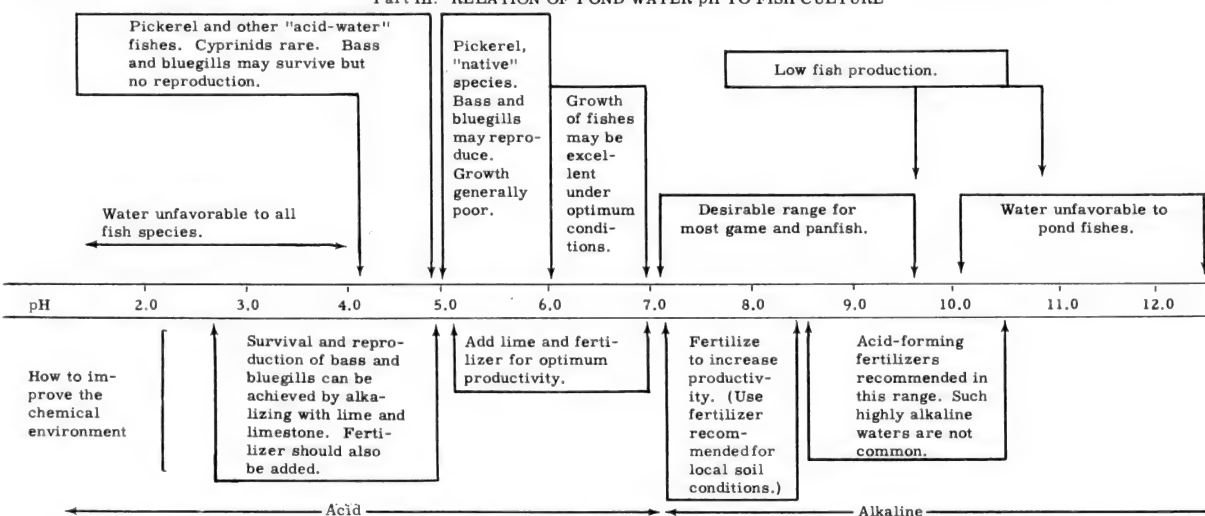
Part I: TEMPERATURE, DISSOLVED OXYGEN AND CARBON DIOXIDE: FERTILIZED AND UNFERTILIZED PONDS (SOUTHERN U.S.A)
F = fertilized pond, area 1.3 acres, maximum depth 9 ft, bottom sample taken at 5 ft., 11 applications of 100 lb of 8-8-2 (N-K-P) per acre; U = unfertilized pond, 1.8 acres, maximum depth 9 ft, bottom sample taken at 7.5 ft. Averages are from 4 depths.

Month	Temperature, °C						Oxygen, ppm						Carbon Dioxide, ppm					
	Surface		Bottom		Average		Surface		Bottom		Average		Surface		Bottom		Average	
	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F	U	F
1 April	21.0	23.5	17.0	15.5	18.9	19.0	4.1	9.0	1.9	1.3	4.3	4.4	3.3	2.2	4.4	3.3	4.7	3.0
2 May	23.8	26.2	20.5	18.5	22.3	22.5	5.6	7.5	0.6	0.5	3.8	2.1	9.7	13.2	20.9	58.4	13.2	28.0
3 June	23.0	28.0	22.0	24.0	22.8	26.2	4.9	3.4	3.1	0.6	4.1	1.5	3.9	8.8	9.9	70.9	6.5	28.3
4 July	27.2	29.0	25.2	26.0	26.2	27.7	4.2	4.2	0.9	1.0	2.7	2.2	3.8	3.7	11.0	18.1	6.6	10.4
5 August	29.0	30.0	26.5	28.5	23.1	29.2	3.0	2.2	1.0	0.5	2.2	1.2	6.5	11.0	11.0	52.2	15.1	24.1
6 September	24.5	26.0	23.7	24.7	24.2	25.3	4.2	3.4	2.1	1.9	2.7	2.8	4.9	7.7	13.7	20.9	8.4	11.9
7 October	20.5	21.0	20.5	20.0	20.6	20.5	4.3	3.7	4.5	3.7	4.8	3.6	3.7	6.9	7.7	8.7	4.8	7.3
8 November	17.0	17.0	17.0	17.0	17.0	17.0	4.9	4.1	5.1	4.7	5.0	4.5	2.2	3.3	2.2	4.4	2.7	4.4

Part II: RELATION OF POND WATER OXYGEN CONTENT TO FISH CULTURE



Part III: RELATION OF POND WATER pH TO FISH CULTURE



388. SHADE TOLERANCE: SHRUBS AND HERBACEOUS PLANTS

T = highly tolerant; t = moderately tolerant; I = intermediate; ♀ = moderately intolerant; T = highly intolerant.

Species	Tolerance	Species	Tolerance	Species	Tolerance
Shrubs		Herbaceous Flowers		Herbaceous Flowers (concluded)	
1 Abelia (<i>Abelia grandiflora</i>)	I	39 Ageratum (<i>Ageratum</i> spp)	I	77 Spiderwort (<i>Tradescantia virginiana</i>)	T
2 Barberrry (<i>Berberis thunbergii</i>)	♀	40 Alyssum (<i>Alyssum</i> spp)	I	78 Squill (<i>Scilla siberica</i>)	T
3 Beauty bush (<i>Kolkwitzia amabilis</i>)	I	41 Anemone (<i>Anemone quinquefolia</i>)	t	79 Trillium (<i>Trillium grandiflorum</i>)	t
4 Blueberry (<i>Vaccinium corymbosum</i>)	T	42 Arbutus (<i>Epigaea repens</i>)	t	80 Trillium (<i>T. undulatum</i>)	T
5 Boxwood (<i>Buxus microphylla</i>)	I	43 Aster (<i>Aster</i> spp)	I	81 Twin flower (<i>Linnaea borealis</i>)	T
6 Buckthorn (<i>Rhamnus cathartica</i>)	t	44 Baneberry (<i>Actaea</i> spp)	t	82 Violet (<i>Viola papilionacea</i>)	T
7 Burning bush (<i>Evonymus atropurpurea</i>)	I	45 Blood root (<i>Sanguinaria canadensis</i>)	t	83 Zinnia (<i>Zinnia</i> spp)	I
8 Chokeberry (<i>Aronia atropurpurea</i>)	♀	46 Blue bead (<i>Clintonia borealis</i>)	T	Grasses	
9 Coralberry (<i>Symphoricarpos orbiculatus</i>)	I	47 Bluebell (<i>Polemonium reptans</i>)	I	84 Bluegrama (<i>Bouteloua gracilis</i>)	♀
10 Cranberry (<i>Viburnum opulus</i>)	T	48 Calendula (<i>Calendula</i> spp)	I	85 Bluegrass (<i>Poa trivialis</i>)	t
11 Currant (<i>Ribes americanum</i>)	T	49 Cardinal flower (<i>Lobelia cardinalis</i>)	I	86 Fescue (<i>Festuca rubra</i>)	t
12 Dogwood (<i>Cornus racemosa</i>)	I	50 Chrysanthemum (<i>Chrysanthemum</i> spp)	I	87 Wheatgrass (<i>Agropyrum cristatum</i>)	I
13 Dogwood (<i>C. stolonifera</i>)	♀	51 Columbine (<i>Aquilegia canadensis</i>)	I	Vegetable Crops	
14 Elderberry (<i>Sambucus canadensis</i>)	I	52 Cone-flower (<i>Rudbeckia triloba</i>)	t	88 Beet (<i>Beta vulgaris</i>)	I
15 Elderberry (<i>S. racemosa</i>)	t	53 Coral bells (<i>Heuchera sanguinea</i>)	I	89 Cauliflower (<i>Brassica oleracea botrytis</i>)	T
16 Firethorn (<i>Pyracantha coccinea</i>)	t	54 Coral root (<i>Corallorhiza maculata</i>)	T	90 Celery (<i>Apium graveolens dulce</i>)	I
17 Forsythia (<i>Forsythia suspensa</i>)	I	55 Cowslip (<i>Mertensia virginica</i>)	I	91 Eggplant (<i>Solanum melongena esculentum</i>)	I
18 Gooseberry (<i>Ribes cynosbati</i>)	T	56 Day lily (<i>Hemerocallis</i> spp)	♀	92 Lettuce (<i>Lactuca sativa</i>)	♀
19 Holly, Japanese (<i>Ilex crenata</i>)	t	57 Foxglove (<i>Digitalis purpurea</i>)	t	93 Tomato (<i>Lycopersicon esculentum</i>)	I
20 Honeysuckle (<i>Lonicera japonica</i>)	t	58 Goldthread (<i>Coptis trifolia</i>)	T	Pteridophytes - Ferns	
21 Honeysuckle (<i>L. sempervirens</i>)	♀	59 Grape-hyacinth (<i>Muscari azureum</i>)	I	94 Beech (<i>Phegopteris polypodioides</i>)	T
22 Honeysuckle (<i>L. tatarica</i>)	I	60 Hepatica (<i>Hepatica triloba</i>)	I	95 Bladder (<i>Cystopteris bulbifera</i>)	t
23 Laurel (<i>Kalmia latifolia</i>)	I	61 Iris (<i>Iris cristata</i> and <i>verna</i>)	I	96 Brake (<i>Pteridium aquilinum</i>)	t
24 Lilac (<i>Syringa vulgaris</i>)	I	62 Jack-in-the-pulpit (<i>Arisaema triphyllum</i>)	T	97 Christmas (<i>Polystichum acrostichoides</i>)	T
25 Mahonia (<i>Mahonia aquifolium</i>)	I	63 Lady's slipper (<i>Cypripedium hirsutum</i>)	t	98 Cinnamon (<i>Osmunda cinnamomea</i>)	t
26 Maple (<i>Acer pennsylvanicum</i>)	t	64 Lady's slipper (<i>C. pubescens</i>)	T	99 Hartford (<i>Lygodium palmatum</i>)	t
27 Mockorange (<i>Philadelphus coronarius</i>)	I	65 Lily (<i>Lilium</i> spp)	♀	100 Hayscented (<i>Dennstaedtia punctilobula</i>)	t
28 Peashrub (<i>Caragana arborescens</i>)	I	66 Monkshood (<i>Aconitum fisheri</i>)	t	101 Interrupted (<i>Osmunda claytoniana</i>)	t
29 Photinia (<i>Photinia villosa</i>)	t	67 Narcissus (<i>Narcissus</i> spp)	T	102 Lady (<i>Asplenium filix-foemina</i>)	T
30 Prickly-ash (<i>Zanthoxylum americanum</i>)	T	68 Oxalis (<i>Oxalis corniculata</i>)	t	103 Maidenhair (<i>Adiantum pedatum</i>)	T
31 Privet (<i>Ligustrum amurense</i>)	t	69 Oxalis (<i>O. violacea</i>)	t	104 Ostrich (<i>Pteris pennsylvanica</i>)	T
32 Rhododendron (<i>Rhododendron</i> spp)	T	70 Periwinkle (<i>Vinca minor</i>)	♀	105 Polypody (<i>Polypodium virginianum</i>)	t
33 Spice bush (<i>Lindera benzoin</i>)	t	71 Petunia (<i>Petunia hybrida</i>)	♀	106 Walking (<i>Camptosorus rhizophyllus</i>)	T
34 Viburnum (<i>Viburnum acerifolium</i>)	T	72 Phlox (<i>Phlox divaricata</i>)	t	107 Wood (<i>Dryopteris marginalis</i>)	T
35 Viburnum (<i>V. dentatum</i>)	t	73 Phlox (<i>P. maculata</i>)	t	Pteridophytes - Fern Allies	
36 Winterberry (<i>Ilex verticillata</i>)	t	74 Phlox (<i>P. paniculata</i>)	I	108 Clubmoss (<i>Lycopodium lucidulum</i>)	T
37 Witch hazel (<i>Hamamelis mollis</i>)	t	75 Plantain lily (<i>Hosta</i> spp)	I	109 Horsetail (<i>Equisetum hyemale</i>)	T
38 Yew (<i>Taxus canadensis</i>)	T	76 Primrose (<i>Primula vulgaris</i>)	I		

389. SHADE TOLERANCE: FOREST TREES

T = highly tolerant; t = moderately tolerant; I = intermediate; ♀ = moderately intolerant; T = highly intolerant.

Species	Tolerance	Species	Tolerance	Species	Tolerance
Broadleaf Trees		Broadleaf Trees (continued)		Broadleaf Trees (concluded)	
1 Ash (<i>Fraxinus</i> spp) ¹	I	26 Hickory (<i>Carya</i> spp)	♀	51 Willow (<i>Salix</i> spp)	T
2 Aspen (<i>Populus</i> spp) ²	T	27 Holly (<i>Ilex opaca</i>)	T	52 Yellow-poplar (<i>Liriodendron tulipifera</i>)	♀
3 Basswood (<i>Tilia</i> spp)	t	28 Honeylocust (<i>Gleditsia triacanthos</i>)	♀	Conifers	
4 Beech (<i>Fagus grandifolia</i>)	T	29 Hophornbeam (<i>Ostrya virginiana</i>)	T	53 Baldcypress (<i>Taxodium distichum</i>)	I
5 Birch (<i>Betula lenta</i>)	I	30 Hornbeam (<i>Carpinus caroliniana</i>)	T	54 Douglas-fir (<i>Pseudotsuga menziesii</i>)	I
6 Birch (<i>B. lutea</i>)	I	31 Horsechestnut (<i>Aesculus hippocastanum</i>)	♀	55 Fir (<i>Abies</i> spp) ⁷	t
7 Birch (<i>B. papyrifera</i>)	♀	32 Laurel (<i>Umbellularia californica</i>)	t	56 Fir (<i>Abies</i> spp) ⁸	t
8 Birch (<i>B. pendula</i>)	♀	33 Locust (<i>Robinia pseudoacacia</i>)	T	57 Fir (<i>A. procera</i>)	♀
9 Buckeye (<i>Aesculus</i> spp)	t	34 Maple (<i>Acer</i> spp) ⁴	T	58 Hemlock (<i>Tsuga</i> spp) ⁹	T
10 Butternut (<i>Juglans cinerea</i>)	♀	35 Maple (<i>Acer</i> spp) ⁵	♀	59 Hemlock (<i>T. mertensiana</i>)	t
11 Catalpa (<i>Catalpa bignonioides</i>)	♀	36 Maple (<i>A. platanoides</i>)	♀	60 Larch (<i>Larix</i> spp)	T
12 Cherry (<i>Prunus serotina</i>)	♀	37 Mountain-ash (<i>Sorbus americana</i>)	I	61 Pine (<i>Pinus</i> spp) ¹⁰	♀
13 Chestnut (<i>Castanea dentata</i>)	I	38 Mulberry (<i>Morus rubra</i>)	I	62 Pine (<i>Pinus</i> spp) ¹¹	T
14 Coffeetree (<i>Gymnocladus dioica</i>)	♀	39 Oak (<i>Quercus</i> spp) ⁶	I	63 Pine (<i>Pinus</i> spp) ¹²	I
15 Cottonwood (<i>Populus deltoides</i>)	T	40 Oak (<i>Q. prinus</i>)	♀	64 Redcedar (<i>Juniperus virginiana</i>)	♀
16 Crabapple (<i>Malus coronaria</i>)	I	41 Papaw (<i>Asimina triloba</i>)	♀	65 Redcedar (<i>Thuja plicata</i>)	T
17 Cucumber tree (<i>Magnolia acuminata</i>)	T	42 Pecan (<i>Carya illinoensis</i>)	♀	66 Port Orford cedar (<i>Chamaecyparis lawsoniana</i>)	t
18 Dogwood (<i>Cornus florida</i>)	T	43 Poplar (<i>Populus nigra</i>)	T	67 Redwood (<i>Sequoia sempervirens</i>)	t
19 Elm (<i>Ulmus</i> spp) ³	I	44 Redbud (<i>Cercis canadensis</i>)	I	68 Sequoia (<i>S. gigantea</i>)	I
20 Elm (<i>U. campestris</i>)	t	45 Serviceberry (<i>Amelanchier arborea</i>)	I	69 Spruce (<i>Picea</i> spp) ¹³	t
21 Fringe-tree (<i>Chionanthus virginica</i>)	I	46 Sumac (<i>Toxicodendron vernix</i>)	t	70 Spruce (<i>P. abies</i>)	T
22 Ginkgo (<i>Ginkgo biloba</i>)	♀	47 Sweetgum (<i>Liquidambar styraciflua</i>)	♀	71 Spruce (<i>P. pungens</i>)	I
23 Hackberry (<i>Celtis occidentalis</i>)	I	48 Sycamore (<i>Platanus occidentalis</i>)	♀	72 Torreya (<i>Torreya californica</i>)	T
24 Hawthorn (<i>Crataegus</i> spp)	♀	49 Tupelo (<i>Nyssa sylvatica</i>)	♀	73 White-cedar (<i>Chamaecyparis thyoides</i>)	T
25 Hawthorn (<i>C. oxyantha</i>)	I	50 Walnut (<i>Juglans nigra</i>)	♀	74 White-cedar (<i>Thuja occidentalis</i>)	t

/1/ *F. americana*, *F. latifolia*, *F. nigra*, *F. pennsylvanica*. /2/ *P. grandidentata*, *P. tremuloides*. /3/ *U. americana*, *U. thomasi*. /4/ *A. saccharum*, *A. spicatum*. /5/ *A. rubrum*, *A. saccharinum*. /6/ *Q. alba*, *Q. lobata*, *Q. macrocarpa*, *Q. palustris*, *Q. rubra*, *Q. velutina*. /7/ *A. balsamea*, *A. lasiocarpa*. /8/ *A. amabilis*, *A. grandis*, *A. concolor*. /9/ *T. canadensis*, *T. heterophylla*. /10/ *Pinus attenuata*, *P. contorta*, *P. coulteri*, *P. echinata*, *P. jeffreyi*, *P. muricata*, *P. ponderosa*, *P. resinosa*, *P. rigida*, *P. taeda*, *P. virginiana*. /11/ *P. banksiana*, *P. palustris*, *P. sabiniana*, *P. sylvestris*. /12/ *Pinus elliotii*, *P. lambertiana*, *P. monticola*, *P. radiata*, *P. strobus*. /13/ *Picea engelmannii*, *P. glauca*, *P. mariana*, *P. rubens*, *P. sitchensis*.

390. EFFECT OF LIGHT ON VARIOUS PROCESSES: PLANTS

Part I: EFFECT OF WAVE LENGTH

Data present the effectiveness of brief dark-period interruption for control of flowering and certain vegetative expressions. For studies of the inhibition or promotion of flowering, plants growing under radiation from carbon arc and incandescent filament lamps for a daily period of about 12 hrs were subjected, at the midpoint of the dark-period, to radiation of known energy and wave length. Values represent relative energy and may be converted to kilowatts per sq cm by multiplying the values in this table by the following factors: cocklebur, 40; soybean, 30; barley (flowering) 35; henbane, 300; lettuce, 2; pea, 160; barley (elongation), 100; tomato, 200.

Effect	Relative Energy Normalized to Maximum Response at Wave Length											
	4400 Å	4800 Å	5000 Å	5200 Å	5400 Å	5600 Å	5800 Å	6200 Å	6600 Å	6800 Å	7000 Å	7200-7600 Å
1 Inhibition of flowering												reverses the response caused by red (6200-6600 Å) for Items 1, 3, 4, 5, 7, and 8.
2 Cocklebur (<i>Xanthium pensylvanicum</i>)	125	173	92	40	8	5.4	2.6	1	1.5	3.1	7	
3 Soybean, Biloxi (<i>Glycine soja</i>)	18	27	17	6	3.7	2	1.3	1	1.3	1.6	3.5	
4 Promotion of flowering												
5 Barley, Wintex (<i>Hordeum vulgare</i>)	218	185	85	35	4	1.8	1.3	1	1.5	4	7	
6 Henbane (<i>Hyoscyamus niger</i>)					4	1.8	1.3	1	1.5	4	7	
7 Promotion of germination												
8 Lettuce, Grand Rapids (<i>Lactuca sativa</i>)						18	10	3	1	1.2	50	
9 Promotion of leaf elongation												
10 Pea, Little Marvel (<i>Pisum sativum</i>)	100	190	200	95	24	10	6.5	1	1	1	1.3	
11 Inhibition of stem elongation												
12 Barley, Colse I (<i>Hordeum vulgare</i>)	250		200	40	20	5	2	1.3	1	2	6	
13 Production of pigmentation (fruit cuticle)												
14 Tomato, Rutgers (<i>Lycopersicon esculentum</i>)	30	30	30	30	20	10	3	1	1	1.2	7	

Part II: EFFECT OF DAY LENGTH ON DEVELOPMENT, EXCLUSIVE OF FLOWER INITIATION

Process Affected		Day Length		Process Affected		Day Length		Process Affected		Day Length	
1 Winter hardening		Short	8	Root thickening		Short	15	Bud elongation		Short	
2 Abelia (<i>Abelia grandiflora</i>)	Short	9	Radish (<i>Raphanus sativus</i>)	Short	15	Orchid (<i>Cattleya trianae</i>)	Short	Pistillate flowers increased		Short	
3 Alfalfa (<i>Medicago sativa</i>)	Short	10	Bulb development	Long	16	Cucumber (<i>Cucumis sativus</i>)	Short	Staminate flowers increased		Long	
4 Tuber development	Short	11	Onion (<i>Allium cepa</i>)	Long	17	Cucumber (<i>C. sativus</i>)	Long	Seed development		Short	
5 Artichoke (<i>Helianthus tuberosus</i>)	Short	12	Runner development	Long	18	Hemp, staminate (<i>Cannabis sativa</i>)	Short	Plantlet development		Long	
6 Potato (<i>Solanum tuberosum</i>)	Short	13	Strawberry (<i>Fragaria chiloensis</i>)	Long	19	Bryophyllum (<i>Bryophyllum pinnatum</i>)	Long				
7 Yam (<i>Dioscorea alata</i>)	Short	14	Stem elongation	Long							
8 Storage root development	Short		Coneflower (<i>Rudbeckia</i> spp)	Long							
9 Dahlia (<i>Dahlia</i> spp)	Short		Henbane, biennial (<i>Hyoscyamus niger</i>)	Long							
10 Fibrous root development	Long		Rye, winter (<i>Secale cereale</i>)	Long							
11 Dahlia (<i>Dahlia</i> spp)	Long		Spinach (<i>Spinacia oleracea</i>)	Long							

Part III: EFFECT OF VARIOUS DAY LENGTHS

Species		Beginning of Test	Time Required for Development at Day Lengths												Photoperiodic Class
			10 hr			12 hr			12.5 hr			13 hr			
			Buds	Fls	Height	Buds	Fls	Height	Buds	Fls	Height	Buds	Fls	Height	
			da	Fls	in	da	Fls	in	da	Fls	in	da	Fls	in	
1	Althea (<i>Hibiscus syriacus</i>)	Mar 27							95	117	30	96	123	48	Long day
2	Amaranth (<i>Gomphrena globosa</i>)	May 13	21	33	8	21	33	10	21	36	11	23	32	8	Day neutral
3	Balsam (<i>Impatiens balsamina</i>)	June 23	20	28	14	20	28	18				20	29	19	Day neutral
4	Bindweed (<i>Convolvulus sepium</i>)	May 19													Long day
5	Bougainvillea (<i>Bougainvillea glabra</i>)	May 24	28	45	38	36	57	40	69	88	56	96	157	60	Short day
6	Calendula (<i>Calendula officinalis</i>)	May 9	26	42	9	26	41	13	26	41	15	26	41	15	Day neutral
7	Caryopteris (<i>Caryopteris incana</i>)	June 5	26	38	13	26	38	16				24	35	16	Short day
8	Cloud grass (<i>Agrostis nebulosa</i>)	May 14										49	58	10	Long day
9	Cobaea (<i>Cobaea scandens</i>)	May 26	24	53	46	36	91	41				55	91	46	Short day
10	Columbine (<i>Aquilegia canadensis</i>)	Mar 27	4	25	19	4	28	19				4	36	30	Short day
11	Cosmos (<i>Cosmos bipinnatus</i>)	May 7	10	17	19	10	24	36	10	17	19	10	19	20	Day neutral
12	Gama-grass (<i>Tripsacum dactyloides</i>)	Mar 31	63	72	64	65	74	56	68	75	45	68	75	67	Short day
13	Goldenrod (<i>Solidago ulmifolia</i>)	Apr 23	39	73	25	45	73	22	69	88	14	49	77	19	Short day
14	Kalanchoe (<i>Kalanchoe laxiflora</i>)	May 8							173	239	38	173	199	47	Day neutral
15	Loosestrife (<i>Steironema ciliatum</i>)	Apr 15							56	65	21	87	93	24	Long day
16	Perilla (<i>Perilla frutescens</i>)	May 17	25	39	22	37	47	27	39	58	30	39	50	25	Short day
17	Periwinkle (<i>Vinca minor</i>)	June 7	18	26	16	18	23	12							Day Neutral
18	Poinsettia (<i>Euphorbia pulcherrima</i>)	May 16	32	65	47	39	44	53	48	180	66	107	179	76	Short day
19	Purpletop (<i>Triodia flava</i>)	May 20	29	38	26	39	44	25	39	46	37	42	47	30	Short day
20	Reed grass (<i>Calamagrostis cinnoides</i>)	Mar 30				58	76	41	63	88	42	70	98	35	Day neutral
21	Rosinweed (<i>Silphium trifoliatum</i>)	Apr 18	89	107	38	89	110	56	68	90	56	68	89	70	Long day
22	Soybean, Biloxi (<i>Glycine soja</i>)	May 25	20	23	9	21	27	14	24	27	18	25	31	16	Short day
23	Spider-flower (<i>Cleome spinosa</i>)	May 31	26	38	28	27	35	28				27	36	34	Day neutral
			13.5 hr			14 hr			14.5 hr			24 hr			
			Buds	Fls	Height	Buds	Fls	Height	Buds	Fls	Height	Buds	Fls	Height	
1	Althea (<i>Hibiscus syriacus</i>)	Mar 27	95	126	46	103	136	44	106	144	52	103	130	44	Long day
2	Amaranth (<i>Gomphrena globosa</i>)	May 13	21	33	9	21	41	15	21	35	12	18	32	10	Day neutral
3	Balsam (<i>Impatiens balsamina</i>)	June 23	20	28	17							30	38	21	Day neutral
4	Bindweed (<i>Convolvulus sepium</i>)	May 19	44	59	40							35	49	45	Long day
5	Bougainvillea (<i>Bougainvillea glabra</i>)	May 24	145	164	75	103	153	50	143	157	53	131	157		Short day
6	Calendula (<i>Calendula officinalis</i>)	May 9	26	47	20	26	41	18	26	44	20	26	41	17	Day neutral
7	Caryopteris (<i>Caryopteris incana</i>)	June 5				54	71	28				59	71	28	Short day
8	Cloud grass (<i>Agrostis nebulosa</i>)	May 14	48	58	13	37	45	11	35	41	16	34	48	11	Long day
9	Cobaea (<i>Cobaea scandens</i>)	May 26				60	92	60				64	97	60	Short day
10	Columbine (<i>Aquilegia canadensis</i>)	Mar 27				14	36	30				4	36	30	Short day
11	Cosmos (<i>Cosmos bipinnatus</i>)	May 7	10	15		10	21	19	10	24	26	10	19	17	Day neutral
12	Gama-grass (<i>Tripsacum dactyloides</i>)	Mar 31	68	76	58	81	89	56	82	89	60	82	89	65	Short day
13	Goldenrod (<i>Solidago ulmifolia</i>)	Apr 23	58	82	32	57	88	36	85	108	30	67	114	36	Short day
14	Kalanchoe (<i>Kalanchoe laxiflora</i>)	May 8				173	192	51	173	204	50	173	192	51	Day neutral
15	Loosestrife (<i>Steironema ciliatum</i>)	Apr 15	49	61	19	48	65	25	49	68	23	49	68	20	Long day
16	Perilla (<i>Perilla frutescens</i>)	May 17	49	70	38	53	83	41	62	96	47	93	114	50	Short day
17	Periwinkle (<i>Vinca minor</i>)	June 7										18	23	12	Day neutral
18	Poinsettia (<i>Euphorbia pulcherrima</i>)	May 16	162	191	74	163	193	76	163	195	91	158	197	70	Short day
19	Purpletop (<i>Triodia flava</i>)	May 20	43	51	45	50	56	25	69	87	51	92	103	42	Short day
20	Reed grass (<i>Calamagrostis cinnoides</i>)	Mar 30	63	84	41	57	84	46	67	91	45	60	84	37	Day neutral
21	Rosinweed (<i>Silphium trifoliatum</i>)	Apr 18	65	89	83	65	89	76	54	79	54	54	78	57	Long day
22	Soybean, Biloxi (<i>Glycine soja</i>)	May 25	34	37	19	42	48	27	50	60	30	81	90	36	Short day
23	Spider-flower (<i>Cleome spinosa</i>)	May 31				28	40	36				28	38	65	Day neutral

391. EFFECT OF LIGHT, WITH TEMPERATURE INTERACTIONS, ON FLOWERING OF PLANTS

Temperature interactions and effects on photoperiodic classification are incomplete. Upon further investigations these data may become modified.

Species	Photoperiodic Class and Light Period ¹	Temperature Interactions and Effects ²	Species	Photoperiodic Class and Light Period ¹	Temperature Interactions and Effects ²
Fruit and Vegetable Crops			Legumes and Other Field Crops (concluded)		
1 Artichoke (<i>Helianthus tuberosus</i>)	s, N		60 Lespedeza (<i>Lespedeza stipulacea</i>)	S(<13.5 hr)	
2 Bean, lima (<i>Phaseolus lunatus</i>)	N, S		61 Soybean, Biloxi and Mandarin (Glycine soja)	S-s	Th;Tq
3 Bean, string (<i>P. vulgaris</i>)	N, S ³		62 Soybean, Mandell (G. soja)	s	Th;Tq
4 Beet, garden (<i>Beta vulgaris</i>)	l	Th;Tl, L	63 Sweetclover (<i>Melilotus alba</i>)	L	
5 Cabbage (<i>Brassica pekinensis</i>)	l	Th;Tl, L	64 Tobacco (<i>Nicotiana tabacum</i>) ⁵	N	
6 Chicory (<i>Cichorium intybus</i>)	L	Th;Tl, N	65 Tobacco, Havana (N. tabacum)	l	
7 Carrot (<i>Daucus carota</i>)	N	Ve(4-10°C)	66 Tobacco, Md. Mammoth (N. tabacum)	S(<14 hr)	Th;<13°C, N
8 Celery (<i>Apium graveolens</i>)	N	Ve(4-10°C)	67 Vetch, spring (<i>Vicia sativa</i>)	l	Th;Tl, N
9 Cucumber (<i>Cucumis sativus</i>)	N		Ornamental Plants		
10 Dill (<i>Anethum graveolens</i>)	L(>11 hr)		68 Althea (<i>Hibiscus syriacus</i>)	L(>12 hr)	
11 Lettuce (<i>Lactuca sativa</i>)	l	Th;Tl, N	69 Aster (<i>Callistephus chinensis</i>)	l	Th
12 Onion (<i>Allium cepa</i>)	l, s, N	Tl	70 Azalea, coral bell (<i>Rhododendron</i> sp)	N	
13 Pea (<i>Pisum sativum</i>)	N, l		71 Balsam (<i>Impatiens balsamina</i>)	N	
14 Pepper (<i>Capsicum annuum</i>)	N, s	TP	72 Begonia (<i>Begonia semperflorens</i>)	N	Tl;Th, l
15 Potato (<i>Solanum tuberosum</i>)	l, s, N		73 Bryophyllum (<i>Bryophyllum pinnatum</i>)	S(<12 hr)	
16 Radish (<i>Raphanus sativus</i>)	L		74 Cactus (<i>Zygocactus truncatus</i>)	s	Tl(18°C);13°C, N
17 Spinach (<i>Spinacia oleracea</i>)	L(>13 hr)	Ve ⁴	75 Chrysanthemum (<i>Chrysanthemum frutescens</i>)	L	
18 Strawberry (<i>Fragaria chiloensis</i>) ⁵	S(<10 hr)	Tq	76 Chrysanthemum (C. indicum)	S(<15 hr)	Tq
19 Strawberry, everbearing (<i>F. chiloensis</i>)	l, N		77 Cineraria (<i>Senecio cruentus</i>)	s	
20 Sweetpotato (<i>Ipomoea batatas</i>)	S		78 Cornflower (<i>Centaurea cyanus</i>)	l	Th;Tl, N
21 Tomato (<i>Lycopersicon esculentum</i>)	N, l, s	TP	79 Cosmos (<i>Cosmos bipinnatus</i>) ³	s	
22 Turnip (<i>Brassica rapa</i>)	l		80 Cosmos, Klondyke (C. sulphureus)	S(<14 hr)	Th and Tl
Grasses			81 Cosmos, orange flare (C. sulphureus)	N	Th;Tl, S
23 Barley, spring (<i>Hordeum vulgare</i>)	l	Vo	82 Foxglove (<i>Digitalis purpurea</i>)	l	Ve
24 Barley, winter (H. vulgare)	L(>12 hr)	Va(7-9°C)	83 Fuchsia (<i>Fuchsia hybrida</i>)	N	Th
25 Beardgrass (<i>Andropogon gerardii</i>)	S(<18 hr)		84 Gardenia (<i>Gardenia jasminoides</i> fort.)	N	
26 Bentgrass (<i>Agrostis palustris</i>)	L(>16 hr)		85 Geranium (<i>Pelargonium hortorum</i>)	N	Tl
27 Bluegrass, annual (<i>Poa annua</i>)	N	Vo	86 Holly, English (<i>Ilex aquifolium</i>)	N	
28 Bluegrass, Kentucky (<i>P. pratensis</i>)	l	Th;Tl, N or s;Ve	87 Hydrangea (<i>Hydrangea macrophylla</i>)	N(?)	Ve
29 Bromegrass (<i>Bromus inermis</i>)	L(>12.5 hr)	Va	88 Kalanchoe (<i>Kalanchoe blossfeldiana</i>)	S(<12 hr)	
30 Broomsedge (<i>Andropogon virginicus</i>)	s(12-14.5 hr)		89 Larkspur (<i>Delphinium cultorum</i>)	L	Tl;Th, N
31 Canary-grass (<i>Phalaris arundinacea</i>)	L(>12.5 hr)		90 Morning glory (<i>Ipomoea hederacea</i>)	S	
32 Cloudgrass (<i>Agrostis nebulosa</i>)	L(>13 hr)		91 Morning glory (I. purpurea)	S ¹¹	
33 Corn (<i>Zea mays</i>)	N, S		92 Orchid (<i>Cattleya trianae</i>)	S	
34 Fescue (<i>Festuca elatior</i>)	L		93 Pansy (<i>Viola tricolor</i>)	N	Tl
35 Foxtail (<i>Alopecurus pratensis</i>)	L(>9 hr)	Tl;Va, Vo ⁶	94 Petunia (<i>Petunia hybrida</i>)	l	Th;Tl, N
36 Oat (<i>Avena sativa</i>)	L(>9 hr)	Ve	95 Phlox (<i>Phlox paniculata</i>)	L	Th
37 Orchardgrass (<i>Dactylis glomerata</i>)	L(>12 hr)	Th	96 Poinsettia (<i>Euphorbia pulcherrima</i>)	S(<12.5 hr)	Tl ¹²
38 Rice, summer (<i>Oryza sativa</i>)	N	Th	97 Salvia (<i>Salvia splendens</i>)	s	Th;Tl, N
39 Rice, winter (O. sativa)	S(<12 hr)	Th	98 Sedum (<i>Sedum spectabile</i>)	L(>13 hr)	
40 Rye, spring (<i>Secale cereale</i>)	l	Tl;Vo	99 Snapdragon (<i>Antirrhinum majus</i>)	l	Th;Tl, N
41 Rye, winter (S. cereale)	l	Va	100 Stock, German (<i>Matthiola incana</i>)	l	Th;Tl, N
42 Ryegrass, Italian (<i>Lolium italicum</i>)	L(>11 hr)	Va	101 Tephrosia (<i>Tephrosia candida</i>)	IM(10-13.2 hr)	
43 Ryegrass, early perennial (L. perenne)	L(>9 hr)	Ve	102 Violet (<i>Viola papilionacea</i>)	S(<11 hr) ¹³	Th;Tq
44 Ryegrass, late perennial (L. perenne)	L(>13 hr)	Ve	Field Weeds		
45 Sorghum (<i>Sorghum vulgare</i>)	l	Th;Tl, N	103 Cocklebur (<i>Xanthium pennsylvanicum</i>)	S(<15.5 hr)	Tq
46 Sudan (<i>Holcus sudanensis</i>)	s		104 Coneflower (<i>Rudbeckia bicolor</i>)	L(>10 hr)	Th
47 Sugar cane (<i>Saccharum officinarum</i>) ⁵	s		105 Coneflower (R. hirta)	L(>12 hr)	
48 Sugar cane, var. 28 NG 292	IM(12-14 hr)		106 Daisy (<i>Chrysanthemum leucanthemum</i>)	L	
49 Timothy, hay (<i>Phleum pratensis</i>)	L(>12 hr)		107 Dog fennel (<i>Anthemis cotula</i>)	l	Th;Tl, N
50 Timothy, pasture (<i>P. nodosum</i>)	L(>14.5 hr)		108 Goldenrod (<i>Solidago</i> spp) ¹⁴	S	
51 Wheat, spring (<i>Triticum aestivum</i>)	l	Vo	109 Henbane, annual (<i>Hyoscyamus niger</i>)	L(>10 hr)	Tq
52 Wheat, winter (T. aestivum) ⁵	L(>12 hr)	Va	110 Henbane, biennial (H. niger)	L	Tq;Ve
53 Wheatgrass (<i>Agropyron smithii</i>)	L(>10 hr)		111 Jimson weed (<i>Datura stramonium</i>)	s ¹⁵	
Legumes and Other Field Crops			112 Lamb's-quarters (<i>Chenopodium album</i>)	S	
54 Alfalfa (<i>Medicago sativa</i>)	l	Th;Tl, N ⁷	113 Mallow (<i>Malva verticillata</i>)	s	Th(23°C);18°C, N
55 Beet, sugar (<i>Beta vulgaris</i>)	L	Tl(7-9°C);Ve	114 Nightshade (<i>Solanum nigrum</i>)	N	Tl;Th, l
56 Clover (<i>Trifolium</i> spp) ⁸	L		115 Primrose, evening (<i>Oenothera biennis</i>)	l	Tl
57 Clover (<i>Trifolium</i> spp) ⁹	l	Tl	116 Ragweed (<i>Ambrosia artemisiifolia</i>)	S	
58 Clover, red (T. pratense) ¹⁰	L(>12 hr)		117 Sow-thistle (<i>Sonchus oleraceus</i>)	l	
59 Cotton (<i>Gossypium hirsutum</i>)	N, s	Tq	118 Tumbleweed (<i>Amaranthus graecizans</i>)	s	Th

/1/ L=long day required; l=long day favorable; S=short day required; N=day neutral; IM=intermediate. Where there is more than one symbol of classification, varietal differences occur, the most common class being entered first. Classification is followed in parentheses by light period for flowering (>12 hr should be interpreted as 12 hr or more; <12 hr, as 12 hr or less). /2/ Tl=indicated photoperiodic response occurs at relatively low temperatures (plant may also flower at other day lengths at higher temperatures), or reproductive development is promoted by low temperatures during photoperiodic induction; Th=indicated response occurs at relatively high temperatures (plant may also flower at other day lengths at lower temperatures), or reproductive development is promoted by high temperatures during photoperiodic induction; Tq=temperature has a quantitative effect on the critical day length, i.e., an increase in temperature lowers the minimum limits for long day plants and raises the maximum limits for short day plants, or on the degree of photoperiodic response; Ve=vernalization or other low temperature preconditioning of embryo plants, seedlings, buds, or plants, previous to photoperiodic induction, is essential for complete reproduction development; Va=vernalization promotes reproductive development but is not essential; Vo=vernalization not effective; TP=thermoperiodic, i.e., development affected by alternation of temperature between day and night periods. /3/ Photoperiod influences fruit development but floral initiation is not affected. /4/ For some varieties. /5/ Data applicable to most varieties. /6/ Winter varieties, Va; spring varieties, Vo. /7/ Vegetative in warm nights. /8/ Species include crimson clover (*T. incarnatum*), Ladino clover (*T. repens*). /9/ Species include red clover (*T. pratense*), white clover (*T. repens*). /10/ Variety English Montgomery; for American Medium, 1(>9 hr). /11/ Night temperature, 22°C. At 18°C, N; at 13°C, L. /12/ Night temperature, <21°C. At 13-14°C, L. /13/ Production of blue petaliferous flowers; formation of fertile, cleistogamous flowers, L. /14/ Species include: *S. altissima*, *S. fistulosa*, *S. juncea*. For *S. cutleri*, L. /15/ Becomes N with aging of plant.

392. DAY LENGTHS AND MEAN TEMPERATURES: NORTHERN AND SOUTHERN LATITUDES

Part I: SUMMATION OF DAY LENGTHS IN NORTHERN AND SOUTHERN LATITUDES, BEGINNING DECEMBER 21

Values for northern latitudes are followed in parentheses by those for southern latitudes.

Date	Latitude	Daylight and Twilight Periods			Percentage Change when Compared with:	
		Daylight ¹ min	Twilight ² min	Total min	Equator	Preceding Latitudes
1	0°	8729(8729)	552(552)	9281(9281)		
2	10°	8312(9148)	552(552)	8864(9700)	-4.5(+4.5)	-4.5(+4.5)
3	20°	7870(9602)	576(600)	8446(10,202)	-9.0(+9.9)	-4.7(+5.2)
4	30°	7362(10,129)	624(662)	7986(10,791)	-14.0(+16.3)	-5.4(+5.8)
5	40°	6730(10,796)	738(792)	7468(11,588)	-19.5(+24.3)	-6.5(+7.4)
6	50°	5934(11,767)	922(1072)	6856(12,839)	-26.1(+38.3)	-8.2(+10.8)
7	0°	18,913(18,913)	1168(1168)	20,081(20,081)		
8	10°	18,039(19,793)	1192(1196)	19,231(20,989)	-4.2(+4.5)	-4.2(+4.5)
9	20°	17,109(20,748)	1248(1276)	18,357(22,024)	-8.6(+9.7)	-4.5(+4.9)
10	30°	16,047(21,857)	1352(1418)	17,399(23,275)	-13.4(+15.9)	-5.2(+5.7)
11	40°	14,722(23,263)	1578(1696)	16,300(24,959)	-18.8(+24.3)	-6.3(+7.2)
12	50°	12,850(25,293)	1974(2282)	14,824(27,575)	-26.2(+37.3)	-9.0(+10.5)
13	0°	31,275(31,275)	1916(1916)	33,191(33,191)		
14	10°	29,925(32,642)	1940(1962)	31,865(34,604)	-4.0(+4.2)	-4.0(+4.2)
15	20°	28,494(34,126)	2038(2086)	30,532(36,212)	-8.0(+9.1)	-4.2(+4.3)
16	30°	26,859(35,847)	2220(2316)	29,079(38,163)	-12.4(+15.0)	-4.8(+5.4)
17	40°	24,828(38,021)	2572(2752)	27,400(40,773)	-17.4(+22.8)	-5.8(+6.8)
18	50°	21,974(41,141)	3196(3654)	25,170(44,795)	-24.2(+35.0)	-8.1(+9.9)
19	0°	41,453(41,453)	2514(2514)	43,967(43,967)		
20	10°	39,805(43,135)	2556(2578)	42,363(45,713)	-3.7(+4.0)	-3.7(+4.0)
21	20°	38,060(44,959)	2682(2730)	40,742(47,689)	-7.3(+8.5)	-3.8(+4.3)
22	30°	36,071(47,074)	2920(3032)	38,991(50,106)	-11.3(+14.0)	-4.3(+5.1)
23	40°	33,605(49,736)	3360(3580)	36,965(53,316)	-15.9(+21.3)	-5.2(+6.4)
24	50°	30,159(53,543)	4152(4694)	34,311(58,237)	-22.0(+32.4)	-7.2(+9.2)
25	0°	52,355(52,355)	3144(3144)	55,499(55,499)		
26	10°	50,499(54,273)	3188(3244)	53,687(57,497)	-3.3(+3.6)	-3.3(+3.6)
27	20°	48,536(56,344)	3344(3412)	51,880(59,756)	-6.5(+7.7)	-3.4(+3.9)
28	30°	46,299(58,752)	3642(3780)	49,941(62,532)	-10.0(+12.7)	-3.7(+5.1)
29	40°	43,539(61,775)	4184(4432)	47,723(66,207)	-14.0(+19.3)	-4.4(+5.9)
30	50°	39,693(66,070)	5142(5738)	44,835(71,808)	-19.2(+29.4)	-6.0(+8.4)
31	0°	62,527(62,527)	3732(3732)	66,259(66,259)		
32	10°	60,581(64,561)	3776(3812)	64,357(68,373)	-2.9(+3.2)	-2.9(+3.2)
33	20°	58,523(66,750)	3960(4028)	62,483(70,778)	-5.7(+6.8)	-2.9(+3.5)
34	30°	56,184(69,297)	4314(4452)	60,498(73,749)	-8.7(+11.3)	-3.2(+4.2)
35	40°	53,303(72,497)	4940(5202)	58,243(77,699)	-12.1(+17.3)	-3.7(+5.4)
36	50°	49,293(77,034)	6038(6668)	55,331(83,702)	-16.5(+26.3)	-5.0(+7.7)
37	0°	74,877(74,877)	4446(4446)	79,323(79,323)		
38	10°	72,972(76,903)	4490(4526)	77,462(81,429)	-2.3(+2.6)	-2.3(+2.6)
39	20°	70,954(79,084)	4708(4776)	75,662(83,860)	-4.6(+5.7)	-2.3(+3.9)
40	30°	68,668(81,626)	5130(5268)	73,798(86,894)	-7.0(+9.9)	-2.5(+3.6)
41	40°	65,856(84,826)	5858(6120)	71,714(90,946)	-9.6(+14.6)	-2.8(+4.7)
42	50°	61,943(89,364)	7144(7764)	69,087(97,128)	-12.9(+22.4)	-3.7(+6.8)
43	0°	85,050(85,050)	5034(5034)	90,084(90,084)		
44	10°	83,297(86,949)	5078(5114)	88,375(92,063)	-1.9(+2.2)	-1.9(+2.2)
45	20°	81,438(88,996)	5324(5392)	86,762(94,388)	-3.7(+4.8)	-1.8(+2.5)
46	30°	79,336(91,396)	5810(5940)	85,146(97,333)	-5.5(+8.0)	-1.9(+3.1)
47	40°	76,758(94,417)	6638(6876)	83,396(101,293)	-7.4(+12.4)	-2.0(+4.1)
48	50°	73,160(98,718)	8084(8670)	81,244(107,388)	-9.8(+19.2)	-2.6(+6.0)
49	0°	96,678(96,678)	5708(5708)	102,386(102,386)		
50	10°	95,221(98,311)	5778(5800)	100,999(104,111)	-1.4(+1.7)	-1.4(+1.7)
51	20°	93,674(100,077)	6062(6110)	99,736(106,187)	-2.6(+3.7)	-1.2(+2.0)
52	30°	91,942(102,154)	6610(6722)	98,552(108,876)	-3.7(+6.3)	-1.2(+2.5)
53	40°	89,813(104,795)	7558(7766)	97,371(112,561)	-4.9(+9.9)	-1.2(+3.4)
54	50°	86,836(108,570)	9224(9734)	96,060(118,304)	-6.2(+15.5)	-1.3(+5.1)
55	0°	106,855(106,855)	6322(6322)	113,177(113,177)		
56	10°	105,752(108,153)	6394(6416)	112,146(114,569)	-0.9(+1.2)	-0.9(+1.2)
57	20°	104,585(109,564)	6712(6754)	111,297(116,318)	-1.7(+2.8)	-0.8(+1.5)
58	30°	103,290(111,238)	7338(7422)	110,628(118,660)	-2.3(+4.8)	-0.6(+2.0)
59	40°	101,709(113,383)	8406(8566)	110,115(121,949)	-2.7(+7.8)	-0.5(+2.8)
60	50°	99,507(116,484)	10,300(10,708)	109,807(127,192)	-3.0(+12.4)	-0.3(+4.3)
61	0°	119,216(119,216)	7070(7070)	126,286(126,286)		
62	10°	118,634(120,007)	7172(7172)	125,806(127,179)	-0.4(+0.7)	-0.4(+0.7)
63	20°	118,033(120,876)	7528(7556)	125,561(128,432)	-0.6(+1.7)	-0.2(+1.0)
64	30°	117,391(121,932)	8248(8302)	125,639(130,234)	-0.5(+3.1)	+0.1(+1.4)
65	40°	116,636(123,312)	9478(9572)	126,114(132,884)	-0.1(+5.2)	+0.4(+2.0)
66	50°	115,608(125,343)	11,710(11,952)	127,318(137,295)	+0.8(+8.7)	+1.0(+3.3)
67	0°	133,762(133,762)	7978(7978)	141,740(141,740)		
68	10°	133,871(133,871)	8092(8092)	141,963(141,963)	+0.2(+0.2)	+0.2(+0.2)
69	20°	134,014(134,014)	8516(8516)	142,530(142,530)	+0.6(+0.6)	+0.4(+0.4)
70	30°	134,239(134,239)	9342(9342)	143,581(143,581)	+1.3(+1.3)	+0.7(+0.7)
71	40°	134,582(134,582)	10,790(10,790)	145,372(145,372)	+2.6(+2.6)	+1.2(+1.2)
72	50°	135,144(135,144)	13,482(13,482)	148,626(148,626)	+4.8(+4.8)	+2.2(+2.2)

/1/ Computed from time of sunrise to time of sunset. /2/ Civil twilight.

Part II: PERCENTAGE DIFFERENCE IN SUMMATION OF DAY LENGTH BETWEEN NORTHERN AND SOUTHERN LATITUDES, BEGINNING DECEMBER 21

Percentage difference is presented in terms of southern latitudes.

Southern Latitude	Date	Northern Latitude				
		10°	20°	30°	40°	50°
1	Jan 1	-8.6	-12.9	-17.7	-23.0	-29.3
2	Feb 1	-7.9	-11.8	-16.0	-20.8	-27.3
3	Mar 1	-6.6	-9.8	-13.1	-17.0	-22.0
4	Apr 1	-4.9	-7.1	-9.4	-11.9	-15.2
5	May 1	-3.0	-4.2	-5.3	-6.5	-7.7
6	June 1	-1.1	-1.3	-1.2	-0.8	+0.1
7	Jan 1	-13.1	-17.2	-21.7	-26.8	-32.8
8	Feb 1	-12.0	-15.7	-19.7	-24.3	-30.5
9	Mar 1	-10.2	-13.2	-16.4	-20.1	-25.0
10	Apr 1	-7.6	-9.8	-12.0	-14.5	-17.6
11	May 1	-4.9	-6.1	-7.2	-8.3	-9.5
12	June 1	-2.0	-2.2	-2.2	-1.8	-0.9
13	Jan 1	-17.9	-21.7	-26.0	-30.8	-36.5
14	Feb 1	-16.5	-20.0	-23.8	-28.2	-34.0
15	Mar 1	-14.1	-17.0	-20.1	-23.7	-28.3
16	Apr 1	-10.9	-12.9	-15.1	-17.5	-20.5
17	May 1	-7.2	-8.4	-9.5	-10.6	-11.8
18	June 1	-3.4	-3.6	-3.5	-3.2	-2.2
19	Jan 1	-23.5	-27.1	-31.1	-35.6	-40.8
20	Feb 1	-21.8	-25.1	-28.7	-32.8	-38.3
21	Mar 1	-18.9	-21.6	-24.6	-27.9	-32.3
22	Apr 1	-14.8	-16.8	-18.9	-21.1	-24.0
23	May 1	-10.3	-11.4	-12.4	-13.5	-14.7
24	June 1	-5.3	-5.5	-5.5	-5.1	-4.2
25	Jan 1	-31.0	-34.2	-37.8	-41.8	-46.6
26	Feb 1	-28.9	-31.8	-35.1	-38.8	-43.8
27	Mar 1	-25.2	-27.8	-30.5	-33.5	-37.6
28	Apr 1	-20.2	-22.1	-24.0	-26.2	-28.9
29	May 1	-14.7	-15.7	-16.7	-17.7	-18.8
30	June 1	-8.4	-8.5	-8.5	-8.1	-7.3

Part III: SEASONAL TIME SCALE OF DAY AND NIGHT HOURS

Northern Hemisphere		Dec 21	Jan 21 Nov 21	Feb 21 Oct 21	Mar 21 Sept 21	Apr 21 Aug 21	May 21 July 21	June 21
Par- allel	Period	Hours						
1°	Day	12.0	12.0	12.0	12.0	12.0	12.0	12.0
	Night	12.0	12.0	12.0	12.0	12.0	12.0	12.0
10°	Day	11.5	11.6	11.7	12.0	12.3	12.4	12.5
	Night	12.5	12.4	12.3	12.0	11.7	11.6	11.5
20°	Day	10.8	11.0	11.4	12.0	12.6	13.0	13.2
	Night	13.2	13.0	12.6	12.0	11.4	11.0	10.8
30°	Day	10.2	10.4	11.1	12.0	12.9	13.6	13.8
	Night	13.8	13.6	12.9	12.0	11.1	10.4	10.2
40°	Day	9.3	9.7	10.6	12.0	13.4	14.3	14.7
	Night	14.7	14.3	13.4	12.0	10.6	9.7	9.3
50°	Day	8.0	8.6	10.1	12.0	13.9	15.4	16.0
	Night	16.0	15.4	13.9	12.0	10.1	8.6	8.0
60°	Day	5.9	6.9	9.2	12.0	14.8	17.1	18.1
	Night	18.1	17.1	14.8	12.0	9.2	6.9	5.9
70°	Day	0	1.5	7.4	12.0	16.6	22.5	24.0
	Night	24.0	22.5	16.6	12.0	7.4	1.5	0
80°	Day	0	0	0	12.0	24.0	24.0	24.0
	Night	24.0	24.0	24.0	12.0	0	0	0
90°	Day	0	0	0	12.0	24.0	24.0	24.0
	Night	24.0	24.0	24.0	12.0	0	0	0
Southern Hemisphere		June 21	May 21 July 21	Apr 21 Aug 21	Mar 21 Sept 21	Feb 21 Oct 21	Jan 21 Nov 21	Dec 21

393. GALVANOTAXIS AND OSCILLOTAXIS: ANIMALS

The term "galvanotaxis" is applied to the physiological response toward an electrode exhibited by an organism placed in a direct current field. If the organism aligns itself parallel to the current lines, and faces and migrates toward the anode, the response is termed "anodal galvanotaxis." Similarly, if the organism reacts in a like manner to stimulation from the cathode, the action is called "cathodal galvanotaxis." When a movement is started in one direction and then is reversed, the response is "biphasic." When an organism in an alternating current field takes a position at right angles to the current lines, and moves parallel to the electrode, the term "oscillotaxis" is used. A=anode; AG=anodal galvanotaxis; C=cathode; CG=cathodal galvanotaxis; BP=biphasic; OT=oscillotaxis; NR=no response; R=response (described in footnotes) not defined by other symbols.

Part I: GALVANOTAXIS		Part I: GALVANOTAXIS		Part I: GALVANOTAXIS	
Organism	Response	Organism	Response	Organism	Response
Protozoa		Platyhelminthes		Arthropoda (concluded)	
Rhizopoda		Turbellaria		Astacus fluviatilis	AG ^{21, 22}
1 Ameba diffluens	CG ¹	48 Dendrocoelum lacteum	CG	89 Bosmina longispina	AG or CG
2 A. limax	CG ¹	49 Leptoplanea variabilis	CG	90 Chydorus sphaericus	AG or CG
3 A. proteus	CG ¹	50 Planaria agilis	CG ^{13, 14}	91 Cyclops viridis	AG or CG
4 A. verrucosa	CG ¹	51 P. dorotocephala	CG ^{13, 14}	92 C. strenuus	AG or CG
5 A. doleini	NR	52 P. gonocephala	CG ^{13, 14}	93 Cyclopyris ovum	CG
Flagellata		53 P. maculata	CG ^{13, 14}	94 Cyprinotus incongruens	CG
6 Chilomonas paramecium	CG-AG ²	54 P. polychroa	CG ^{13, 14}	95 Daphnia longissima	AG or CG
7 Euglena viridis	NR ³	55 P. simplissima	CG ^{13, 14}	96 D. magna	AG or CG
8 Gonium pectorale	CG-AG ⁴	56 P. velata	CG ^{13, 14}	97 D. pulex obtusa	AG or CG
9 Peridinium tabulatum	CG	57 Polycelis nigra	CG ¹⁴	98 Diaptomus denticornis	CG
10 Polythema uvella	AG	58 Stenostoma leucops	CG ¹⁵	99 D. gracilis	CG
11 Trachelomonas hispida	CG	Nemertea		100 D. tatricus	CG
12 Volvox aureus	CG-AG ^{4, 5}	59 Lineus socialis	CG ¹⁵	101 Galathea squamifera	AG ²²
13 V. globator	CG-AG ^{4, 5}	60 L. viridis	CG ¹³	102 Gammarus spp	CG-AG ^{2, 23}
Ciliata		Echinodermata		103 Homarus americanus	R ²⁴
14 Balantidium duodeni	CG ⁶	Asteroidea		104 Moira macrocopa	CG
15 B. elongatum	CG ⁶	61 Asterina gibbosa	BP-CG ¹⁶	105 Notodromas monacha	CG
16 B. entozoon	CG ⁶	62 Asterias glacialis	BP	106 Palaemonetes vulgaris	AG ²²
17 Bursaria truncatella	CG ⁷	63 A. rubens	BP	107 Simocephalus vetulus	AG or CG
18 Chilodon cucullulus	CG ⁷	64 A. tenuispina	BP	Myriopoda	
19 Coleps hirtus	CG	65 Astropecten bispinosus	BP	108 Isobates varicornis	AG
20 Colpidium colpoda	CG ⁷	66 A. mülleri	BP	109 Lithobius validus	AG
21 Colpoda cucullus	CG	67 A. spinulosus	BP	110 Polydesmus complanatus	AG
22 Condyllostoma patens	CG	68 Echinaster sepositus	BP	Insecta	
23 Glaucoma pyriiformis	CG	69 Ophiotrix fragilis	AG ¹⁷	111 Corixa striata	AG
24 Halteria grandinella	CG	70 Ophiura albida	AG	112 Dytiscus marginalis	AG
25 Leucophrys spatula	NR	71 O. texturata	AG	Mollusca	
26 Nyctotherus cordiformis	CG ⁸	72 Solaster papposus	BP-CG ¹⁶	113 Limnaea stagnalis	CG
27 Opalina ranarum	CG-AG ^{2, 8}	Echinoidea		114 Planorbis corneus	CG
28 Oxytricha fallax	CG-AG ²	73 Echinus miliaris	NR ¹⁸	Vertebrata	
29 Paramecium aurelia	CG ⁹	74 Sphaerechinus granularis	CG ¹⁷	Cyclostomata	
30 P. bursaria	CG ⁹	75 Strongylocentrotus lividus	AG ^{17, 18}	115 Petromyzon fluviatilis	AG
31 P. caudatum	CG ⁹	76 S. drobachiensis	AG ^{17, 18}	Pisces	
32 P. marinum	CG ⁹	Echiuroidea		116 Acerina cernua	AG
33 P. putrinum	CG ⁹	77 Echiurus crysanthophorus	AG ¹³	117 Apodes spp	AG
34 Pleuronema chrysalis	CG	Annelida		118 Cyprinus auratus	AG ²⁵
35 Spirostomum ambiguum	CG ⁷	Chaetopoda		119 Esox spp	AG
36 Stentor coerules	CG	78 Dasychone lucullana, larva	CG	120 Gastrosteus aculeatus	AG
37 S. polymorphus	CG	79 Dero limosa	CG	121 Gobio fluviatilis	AG ²⁵
38 S. roeseli	CG	80 Lumbriculus inconstans	CG	122 Leuciscus idus	AG
39 Stylonychia mytilus	CG ⁷	81 Lumbricus terrestris	CG ¹⁴	123 L. rutilus	AG
40 Urocentrum turbo	CG	82 Nereis spp	R ^{14, 19}	124 Phoxinus laevis	AG
41 Uronema marina	CG	83 Tubifex rivulorum	CG	125 Salmo, embryo	AG
42 Urostyla grandis	CG ⁷	Hirudinea		126 Sardinops caerulae	AG
Coelenterata		84 Hirudo medicinalis	R ²⁰	127 Tinca spp	AG
43 Hydra fusca	R ^{10, 11}	Arthropoda		Amphibia	
44 H. viridis	R ^{10, 11}	Crustacea		128 Ambystoma larvae	R ^{25, 26}
45 Pelmatohydra oligactis	R ^{11, 12}	85 Apus cancriformis	AG	129 Rana, adult	NR
46 Pennaria tiarella	R ¹²	86 Asellus aquaticus	AG	130 Rana, tadpole	CG-AG ²
47 Polychorchis penicillata	R ¹²	87 A. communis	AG	131 Triton spp	NR
				132 Triturus torosus	R ^{25, 26}

/1/ AG after treatment with NH₃OH or NH₃ salts. AG when free from substrate. /2/ CG in weak (or medium) fields. AG in strong fields. /3/ Or CG or AG, depending upon culture. /4/ CG in light; AG in dark. /5/ AG after duration in current field. /6/ AG in moderately alkaline field. /6/ AG in moderately alkaline field. /7/ When fixed to substrate turns at right angles with current lines, peristome toward C. /8/ Fresh from frog intestine or with acid treatment. AG out of intestine or with alkali treatment. /9/ In strong field, after moderate currents of long duration, growth in 1/20 M NaCl, suspension in NaCl solution above 0.01-0.1 N, suspension in salt solutions at high concentration, organism may move towards A electrophoretically with anterior end directed towards C. True AG in medium with low calcium concentration. /10/ When fixed bends toward A. /11/ When not fixed bends toward C. /12/ When fixed bends toward C. /13/ Reversed by strychnine. /14/ Bends concavely toward C when at right angles with field. /15/ Reversed by barium salts. /16/ BP, strong fields; CG, weak fields. /17/ Older larvae CG. /18/ Spines and tube feet AG. /19/ After long period in laboratory bends concavely toward A. /20/ Bends anteriorly toward C. /21/ CG in hypertonic salt solutions. /22/ At right angles with field, extremities facing A flexed, facing C extended. /23/ Acid promotes AG, alkali CG. /24/ Gather at, but not directed toward, A. /25/ Bends concavely toward A when at right angles with field. /26/ Bends ventrally concave facing A, dorsally concave facing C, when parallel with field.

Part II: OSCILLOTAXIS		Part II: OSCILLOTAXIS		Part II: OSCILLOTAXIS	
Organism	Response	Organism	Response	Organism	Response
Protozoa		Protozoa (concluded)		Arthropoda (concluded)	
Rhizopoda		12 Vorticella campanulata	NR ⁷	Insecta	
1 Ameba doleini	NR	Platyhelminthes		21 Aeschna larvae	OT
2 A. proteus	OT	13 Dendrocoelum lacteum	OT	22 Dytiscus marginalis	OT
Flagellata		Annelida		Vertebrata	
3 Peridinium umbonatum	R ¹	14 Hirudo medicinalis	OT	Pisces	
Ciliata		Arthropoda		23 Cyprinus auratus	OT
4 Aspidisca spp	R ²	Crustacea		24 Esox lucius	OT
5 Chilodon spp	OT ³	15 Asellus aquaticus	OT	25 Gastrosteus aculeatus	OT
6 Colpidium colpoda	OT ³	16 Gammarus pulex	OT	26 Perca fluviatilis	OT
7 Euplores spp	OT ⁴	17 Palaemon serratus	OT	27 Phoxinus laevis	OT
8 Onychodromus grandis	R ²	18 Peneus caramote	OT	28 Rhodius amarus	OT
9 Paramecium caudatum	OT ⁵	19 Portunus olsatus	OT	29 Salmo lacustris	OT
10 Stentor polymorphus	NR ⁶	Potamobius		Amphibia	
11 Stylonychia mytilus	OT ²	leptodactylus	OT	30 Rana esculenta, tadpole	OT

/1/ Swims in ellipses with long axes at right angles with current. /2/ Swims backwards in circles. /3/ Anterior part describes circle around point in posterior part of organism. /4/ Strong field. Swims in direction of current in weak field. /5/ May make rotary movements with anterior end; posterior end stationary with body describing cone (double cone in stronger field); middle of organism stationary. /6/ Rotation around longitudinal axis accelerated. /7/ When unattached swims in circles.

394. EFFECTS OF HYDROSTATIC PRESSURE

Part I: EFFECTS ON BIOLOGICAL MATERIALS AT PRESSURES IN EXCESS OF 1000 ATMOSPHERES

Material	Approximate Pressure, Atmospheres	Results of Compression	Material	Approximate Pressure, Atmospheres	Results of Compression
Tissues and Tumors					
1 Carcinoma, Brown-Pearce	1000 ¹	Resistant.	33 Antigen, equine serum	4000	Specificity may be changed or unchanged.
2 Chick heart, embryonic	1000-1850	Reduction of subsequent growth in culture.	34 Antitoxin, tetanus, equine	13,500	Gelated, partially inactivated.
3 Erythrocytes	500-3000	Rounded.	35 Filtrate, S. typhi	6000	Superior to cells as immunizing antigen.
4 Sarcoma transplants, rat	5000	Disintegrated.	36 Toxin, diphtheria	13,500	Partially destroyed.
5	1800	Inactivated.	37	17,600	Mostly destroyed.
Bacteria and Fungi					
6 Bacillus anthracis	3000	Partial loss of virulence; death of vegetative cells.	38 Toxin, tetanus	13,500	Greatly attenuated or inactivated.
7 Bacteria, colon	3000	Unaffected.	39 Tuberculin	13,500	Not destroyed.
8 Bacteria, various spp	5000	Vegetative cells killed.	40 Venom, cobra	13,500	Lethality unchanged.
9 Spores, bacterial	12,000	Killed.	Enzymes		
10 Staphylococci	3000	Unaffected.	41 Amylase, laccase, lipase, sucrase (yeast), trypsin (pancreatic), trypsinogen	8,000-15,000	Some completely, others partially inactivated.
11 Streptococci	3000	Killed or retarded in growth.	42 Chymotrypsinogen	7600	pH 3.1-7.6: partly inactivated.
12 Yeast cells	4000-6000	Death, preceded by cytoplasmic flocculation or coagulation.	43 Chymotrypsin, trypsin	7600	pH 3: scarcely affected; pH 7.6: partially inactivated.
Viruses					
13 Avian pest (fowl plague)	4000	Inactivated, but retained antigenicity.	44 Pepsin	7600	pH 2-5.2: largely inactivated.
Bacteriophage vs.: Bacillus megatherium	7000	Inactivated.	45 Pepsin, rennin	6000	Inactivated.
15 B. subtilis	7000	Inactivated.	46 Ribonucleodepolymerase	6000	Reversible diminution in activity under pressure (pressure also affects polymerization of ribonucleic acid alone).
16 Salmonella typhosa	7000	Inactivated.	Proteins		
17 Staphylococci	2000	Inactivated.	47 Albumin, egg	5000	Slight stiffening.
18 Encephalomyelitis (rabbit)	7000	Inactivated.	48	7000	Completely coagulated.
19 Foot and mouth disease	4000	Inactivated.	49	7500	Denatured, coagulated; SH groups exposed.
20 (in guinea pig)	3000	Attenuated.	50 Amylase (active) plus its starch digest	6000	Resynthesis of product resembling initial undigested material.
21 Herpes (rabbit)	3000	Inactivated.	51 Carboxyhemoglobin	9000	Coagulated.
22 Papilloma	4000	No tumors.	52 Gelatin	2000	Gelation accelerated.
23 Rabies (rabbit)	4000	Attenuated.	53 Gelatin gel	3000	Water squeezed out.
24	5000	Inactivated.	54 Globulin, serum (equine)	3,000-13,000	Gelated.
25 Rous sarcoma	1800	Tumors delayed.	55 Insulin	10,000	Coagulated, but not physiologically inactivated.
26 Sarcoma filtrate	4000	No tumors.	56 Trypsin (active) plus its gelatin or serum albumin digest	6000	Resynthesis of product resembling initial undigested material.
27 Shope papilloma	1800	Tumors delayed.			
28 Tobacco mosaic	7500	Inactivated; coagulated.			
29	8000-8700	Inactivated.			
30 Tobacco necrosis	3000-5000	Inactivated.			
31 Vaccinia (rabbit)	4500	Inactivated.			
32 Yellow fever (monkey)	3000	Slightly attenuated.			

1/ Transplantability destroyed by pressure of 1800 atmospheres.

Part II: PHYSIOLOGICAL EFFECTS ON BIOLOGICAL MATERIALS AT PRESSURES NOT EXCEEDING 1000 ATMOSPHERES

Material or Activity	Pressure, Atmospheres	Results of Compression
Cell Division		
1 Eggs (Arbacia)	100-400	Progressive reversible solation of gelated cortical cytoplasm.
2	400	Reversible regression of cleavage furrows; reversible solation of cortical plasmagel.
3 Eggs (annelid, echinoderm, and vertebrate)	100-500	Cleavage-inhibiting pressure increases with temperature (5-30°C).
4 Eggs (Ascaris)	800	Exceptionally resistant to pressure; division not inhibited.
5 Eggs, marine (miscellaneous)	200-400	Reversible inhibition of cleavage.
6 Eggs (Urechis)	300-400	Reversible solation of spindles and asters; movements of chromosomes stopped.
Other Cellular Activities		
7 Ameboid movement (A. proteus, A. dubia)	200-500	Reversible solation of plasmagel; collapsing of pseudopodia; stopping of movement. At higher temperatures greater pressures required to produce effects.
8 Bioluminescence (bacterial)	200-400	Effect depends on temperature. Light intensity decreases at lower, increases at higher, temperature.
9 Ciliary movement	200-400	Temporary increase in beat frequency with each increase of pressure; reverse effect with pressure decrements.
10 "Contraction" of pigment cells (fish)	200-400	"Contraction" phase reversibly inhibited; totally inhibited at higher level.
11 Heart rate, tissue cultured fragments (frog heart)	300	Effect depends on temperature; retardation at lower temperatures, acceleration at higher temperatures.
12 Muscular contraction	200-400	Effect depends on temperature. Tension decreases at lower, increases at higher, temperatures.
13 Protoplasmic streaming (Elodea)	200-400	Solution of cytoplasm; streaming slowed; stopped at 400 atmospheres; reversible.
14 (Pelomyxa)	200-400	Solution of plasmagel; streaming stopped.

394. EFFECTS OF HYDROSTATIC PRESSURE (Concluded)

Part III: EFFECTS ON RATE OF SPECIFIC ENZYME REACTIONS AT PRESSURES LESS THAN 680 ATMOSPHERES

Net volume changes of activation computed according to observed influences of pressure.

Enzyme		Substrate		pH	Temp °C	Observed Volume Change ml/mol	Enzyme		Substrate		pH	Temp °C	Observed Volume Change ml/mol
Kind	Conc mg/ml	Kind	Conc				Kind	Conc mg/ml	Kind	Conc			
1 Amylase, pancreatic	Commercial	Starch	2%		22-23	-28	10 Lysozyme	0.0015	Micrococcus lysodeikticus (whole cells)	± 10 ⁹ cells per ml	6.2-8.7	25	-10 to -24
2 Amylase, salivary	Commercial	Starch	1%		22-23	-22	11 Pepsin	Commercial	Gelatin	0.83%	22-23	-22	
3 Chymotrypsin, crystal	0.00154	Casein	1%	7.7	14.5	-13.5	12 Trypsin, crystal	0.062	α-Benzoyl-L-argininamide	0.04 M	7.76	84.5	-1
4 Dehydrogenase, formic	0.0148	L-Tyrosine, ethylester	0.02 M	7.8	25.1	-13.5	13	0.076	α-Benzoyl-L-argininamide isopropyl ester	0.011 M	8.1	25.2	0
5 Invertase	Commercial	Na formate		5.6-9.5	30	0	14	0.076	β-Lactoglobulin	0.04 M	7.76	25.1	0
6 Invertase	Commercial	Sucrose	10%	4.8	30	-3	15	0.076	Casein	0.5%	8.1	25.1	-36
7 Invertase	Commercial	Sucrose	10%	7.04	30	-5	16	0.5	Casein	0.68%	7.3	55	-1
8 Lipase, pancreatic	Commercial	Sucrose	10%	7.03-70.7	35-45	-69+	17	0.66%	Casein	0.66%	7.3	25-35	-5 to -10
9 Lipase, pancreatic	Commercial	Tributyrin	Very low		22-23	-13							

/1/ Acceleration in observed rate under pressure at these temperatures attributed to retardation by pressure of enzyme dehydration, proceeding with a large volume increase.

395. EFFECTS OF ACCELERATION: MAN

"G" denotes accelerative force in terms of the magnitude of force of gravity at the earth's surface. "Positive G" designates that the force vector acts parallel to the long axis of the body, from foot to head; "transverse G", that force vector acts transverse (perpendicular) to the long axis of the body, and may be (a) prone (from chest to back), or (b) supine (from back to chest). "Negative G" refers to a force vector acting parallel to the long axis of the body from head to foot.

Part I: TOLERANCE TO POSITIVE G

Data are for relaxed young healthy males exposed for 10 seconds. Values in parentheses are ranges, estimate "b" of the 95% range (cf Introduction).

Reaction	G
1 Grayout (Loss of peripheral vision) ¹	4.3(3-5.6)
2 Blackout (Loss of central vision) ¹	4.9(3.4-6.4)
3 Unconsciousness	5.5(3.7-7.3)

/1/ Grayout and blackout for at least 5 sec of 10 sec period.

Part II: G-TOLERANCE TIME LIMITS

Data are for young healthy males actively resisting G. Tolerance limit is unconsciousness. Values in parentheses are ranges of estimates.

Direction of Force	Time in Seconds					
	.001	.01	0.1	1.0	10	100
1 Positive G	70	(30-40)	(19-22.5)	12.5	(6.5-8.2)	(3.5-5.5)
2 Transverse G	200	(60-100)	(38-55)	(25-27.5)	(15-17.5)	(7.2-12.5)
3 Negative G	15	(9.5-16.5)	(6.5-10)	(4.5-6.5)	(3.2-3.8)	(2.2-2.5)

Part III: G-FORCES ACTING UPON MAN AND AIRCRAFT IN FLIGHT

Section 1: Various Turns

Values in parentheses indicate time in seconds required for a 360° turn.

Speed mi/hr	Radius of Turn (Statute Miles)					Speed knots/hr	Radius of Turn (Nautical Miles)				
	0.5	1.0	2.0	5.0	10.0		0.5	1.0	2.0	5.0	10.0
1 100	1.03 (113)	1.01 (226)	1.00 (452)	1.00 (1131)	1.00 (2262)	13 100	1.04 (113)	1.01 (226)	1.00 (452)	1.00 (1131)	1.00 (2262)
2 200	1.42 (56)	1.12 (113)	1.03 (226)	1.01 (565)	1.00 (1131)	14 200	1.53 (56)	1.16 (113)	1.04 (226)	1.01 (565)	1.00 (1131)
3 300	2.49 (38)	1.52 (75)	1.15 (151)	1.03 (377)	1.01 (754)	15 300	2.80 (38)	1.65 (75)	1.20 (151)	1.03 (377)	1.01 (754)
4 400	4.17 (28)	2.26 (57)	1.42 (114)	1.08 (283)	1.02 (565)	16 400	4.76 (28)	2.54 (57)	1.53 (114)	1.10 (283)	1.02 (565)
5 500	6.41 (23)	3.32 (45)	1.87 (90)	1.18 (225)	1.05 (452)	17 500	7.36 (23)	3.78 (45)	2.08 (90)	1.23 (225)	1.07 (452)
6 600	9.18 (19)	4.67 (38)	2.49 (76)	1.35 (188)	1.10 (377)	18 600	10.55 (19)	5.35 (38)	2.81 (76)	1.45 (188)	1.13 (377)
7 700	12.50 (16)	6.28 (32)	3.26 (64)	1.60 (161)	1.18 (323)	19 700	14.30 (16)	7.21 (32)	3.70 (64)	1.74 (161)	1.23 (323)
8 800	16.25 (14)	8.15 (28)	4.17 (56)	1.91 (141)	1.29 (283)	20 800	18.70 (14)	9.39 (28)	4.76 (56)	2.11 (141)	1.36 (283)
9 900	20.60 (13)	10.28 (25)	5.24 (50)	2.28 (126)	1.43 (251)	21 900	23.61 (13)	11.85 (25)	6.00 (50)	2.56 (126)	1.54 (251)
10 1000	25.35 (11)	12.70 (23)	6.41 (46)	2.72 (113)	1.61 (226)	22 1000	29.21 (11)	14.60 (23)	7.35 (46)	3.08 (113)	1.76 (226)
11 1500	57.00 (7)	28.55 (15)	14.30 (30)	5.80 (75)	3.02 (151)	23 1500	65.80 (7)	32.90 (15)	16.45 (30)	6.64 (75)	3.43 (151)
12 2000	101.30 (6)	50.70 (11)	25.40 (23)	10.20 (57)	5.16 (113)	24 2000	117.00 (6)	58.40 (11)	29.20 (23)	11.70 (57)	5.91 (113)

Section 2: Standard 30°/sec Turn
Full turn requires 120 seconds.

Speed mi/hr	Radius, Statute Miles	G	Speed knots/hr	Radius, Nautical Miles	G
1 100	0.53	1.03	13 100	0.53	1.03
2 200	1.06	1.11	14 200	1.06	1.14
3 300	1.59	1.23	15 300	1.59	1.29
4 400	2.12	1.38	16 400	2.12	1.49
5 500	2.65	1.56	17 500	2.65	1.70
6 600	3.18	1.75	18 600	3.18	1.93
7 700	3.71	1.95	19 700	3.71	2.16
8 800	4.24	2.16	20 800	4.24	2.42
9 900	4.77	2.48	21 900	4.77	2.67
10 1000	5.31	2.59	22 1000	5.31	2.93
11 1500	7.96	3.72	23 1500	7.96	4.25
12 2000	10.61	4.88	24 2000	10.61	5.57

396. RADIOISOTOPES USED IN BIOLOGICAL RESEARCH

A = mass number; α = alpha particle; β^+ = positive beta particle from nucleus; β^- = negative beta particle from nucleus; γ = gamma ray; EC = electron capture; Mev = million electron volts; n = neutron; Z = atomic number.

Isotope				Radiation			Average β -Energy ² Mev	Isotope				Radiation			Average β -Energy ² Mev
Z	Symbol	A	Half-life	% ¹	Type	Mev		Z	Symbol	A	Half-life	% ¹	Type	Mev	
1	0	1	13 min	100	β^-	0.78	0.0057	84	51	Sb	124	60 da	10	β^-	0.22
2	1	H	12.4 yr	100	β^-	0.018		85	53				53	β^-	0.61
3	4	Be	53.6 da	100	EC ³			86	6				6	β^-	0.87
4	6	C	5570 yr	100	β^-	0.155	0.050	87	5				5	β^-	1.58
5	11	Na	2.6 yr	90	β^+	0.541		88	5				5	β^-	1.66
6				10	EC ³			89	21				21	β^-	2.31
7				100	γ	1.28	0.540	90					γ 1-6 ⁵	0.603-2.07	0.189
8	11	Na	15.1 hr	100	β^-	1.39		91	53	I	131	8.05 da	2.8	β^-	0.250
9				100	γ	1.37		92					9.3	β^-	0.335
10				100	γ	2.75	0.70	93					87.2	β^-	0.606
11	15	P	14.3 da	100	β^-	1.71		94					0.7	β^-	0.807
12	16	S	87.1 da	100	β^-	0.167		95					6.3	γ	0.080
13	17	Cl	$\sim 3 \times 10^5$ yr	100	β^-	0.714	0.24	96					0.7	γ	0.163
14	19	K	12.52 hr	18	β^-	1.99		97					6.3	γ	0.284
15				82	β^-	3.55		98					80.9	γ	0.364
16				18	γ	1.53	1.395	99					9.3	γ	0.638
17	20	Ca	164 da	100	β^-	0.254		100					2.8	γ	0.723
18	20	Ca	4.8 da	83	β^-	0.66	0.075	101	55	Cs	134	2.3 yr	32	β^-	0.083
19				17	β^-	1.94		102					5	β^-	0.31
20				~ 17	γ	1.31		103					50	β^-	0.655
21	21	Sc	85 da	~ 100	β^-	0.36	0.117	104					13	β^-	0.683
22				~ 100	γ	0.89		105						γ 1-12 ⁵	0.200-1.37
23				~ 100	γ	1.12		106	55	Cs	137	30*3 yr	92	β^-	0.518
24	24	Cr	27.7 da	100	EC ³		0.084	107					8	β^-	1.18
25				~ 10	γ	0.32		108					92	γ	0.662
26	25	Mn	5.7 da	33	β^+	0.58		109	56	Ba	140	13 da	40	β^-	0.48
27				67	EC ³		0.120	110					60	β^-	1.02
28				100	γ	0.73		111						γ 1-4 ⁵	0.03-0.54
29				100	γ	0.94		112	58	Ce	144	282 da	20	β^-	0.16
30				100	γ	1.45	0.099	113					5	β^-	0.26
31	25	Mn	54	100	EC ³			114					75	β^-	0.33
32				100	γ	0.84		115						γ 1-8 ⁵	0.03-0.15
33	26	Fe	2.94 yr	100	EC ³		0.120	116	59	Pr	143	13.8 da	100	β^-	0.93
34					γ	cont ⁴		117	63	Eu	152	13 yr		EC ³	0.70
35	26	Fe	59	~ 46	β^-	0.271		118						γ 1-7 ⁵	0.12-1.09
36				~ 54	β^-	0.462	0.099	119						β^-	1.45
37				3	γ	0.191		120	63	Eu	154	16 yr		EC ³	
38				57	γ	1.10		121						γ	0.12
39				43	γ	1.29	0.099	122						γ	1.12
40	27	Co	57	100	EC ³			123						γ	1.42
41				~ 90	γ	0.014		124						β^-	<0.6
42				~ 90	γ	0.123	0.099	125	77	Ir	192	74.4 da	44	EC ³	0.67
43				~ 10	γ	0.137		126					50	β^-	0.14-1.16
44	27	Co	60	~ 100	β^-	0.306		127					6	γ 1-20 ⁵	0.958
45				~ 100	γ	1.17	0.022	128						γ	0.411
46				100	γ	1.33		129	79	Au	198	2.70 da	99	β^-	0.25
47	28	Ni	63	100	β^-	0.063		130					100	γ	0.30
48	29	Cu	64	38	β^-	0.573	0.12	131	79	Au	199	3.16 da	20	β^-	0.46
49				19	β^+	0.656		132					73	β^-	0.05
50				43	EC ³			133					7	β^-	0.16
51				0.4	γ	1.34	0.003	134					5	γ	0.21
52	30	Zn	65	1.5	β^+	0.325		135					78	γ	0.210
53				98.5	EC ³			136					15	γ	0.279
54				46	γ	1.11	0.150	137	80	Hg	203	47 da	100	β^-	0.018
55	33	As	77	2	β^-	0.43		138					100	γ	0.047
56				98	β^-	0.68		139	82	Pb	210	19 yr	100	β^-	1.17
57					γ 1-7 ⁵	0.023-0.53	0.49	140					100	γ	4.61
58	34	Se	75	100	β^-	0.467		141	83	Bi	210	5.0 da	100	β^-	4.79
59					γ	0.136		142	88	Ra	226	1620 yr	6	α	0.18
60					γ 1-11 ⁵	0.025-0.40	0.150	143					94	α	3.95
61	35	Br	82	100	β^-	0.45		144					6	γ	4.00
62					γ	0.55-2.0		145	90	Th	232	1.39 x 10 ¹⁰ yr	25	α	0.05
63	37	Rb	86	10	β^-	0.68	0.36	146					75	α	5.261
64				90	β^-	1.77		147					25	γ	5.318
65				10	γ	1.08		148	92	U	232	74 yr	~ 32	α	0.06
66	38	Sr	89	100	β^-	1.46	0.49	149					68	α	4.72
67	38	Sr	90	100	β^-	0.53		150					32	γ	4.77
68	42	Mo	99	14	β^-	0.45		151	92	U	233	1.62 x 10 ⁵ yr	2	α	4.82
69				~ 1	β^-	0.87	0.36	152					15	α	0.04-0.09
70				85	β^-	1.23		153					83	α	4.13
71					γ 1-6 ⁵	0.041-0.780		154						γ 1-3 ⁵	4.18
72	47	Ag	110	35	β^-	0.09	0.36	155	92	U	238	4.51 x 10 ⁹ yr	22	α	0.05
73				10	β^-	0.31		156					78	α	5.35
74				50	β^-	0.57		157					22	γ	5.45
75				5	β^-	2.86	0.36	158	94	Pu	238	90 yr	0.1	α	5.50
76					γ 1-14 ⁵	0.116-1.51		159					~ 28	α	0.04-0.15
77	47	Ag	111	8	β^-	0.70		160					72	α	5.10
78				1	β^-	0.80	0.36	161						γ 1-3 ⁵	5.15
79				91	β^-	1.04		162	94	Pu	239	2.44 x 10 ⁴ yr	11	α	0.04-0.38
80				1	γ	0.247		163					89	γ 1-5 ⁵	
81				8	γ	0.340		164							
82	50	Sn	113	100	EC ³										
83				100	γ	0.393									

/1/ Per cent disintegration in which radiation is emitted. /2/ Average energy of all β particles per disintegration. /3/ Electron capture, accompanied by X-rays characteristic of the daughter element. /4/ Continuous X-ray spectrum. /5/ Multiple γ rays with energies in the range indicated; branching ratios not established.

397. RADIOISOTOPES: METABOLIC FEATURES

A = mass number; α = alpha particles; β = beta particles; γ = gamma rays; Z = atomic number.

Isotope			Half-life	Radiation	Absorption	Localization	Elimination
Z	Symbol	A					
11	Na	24	15.1 hr	β, γ	Complete	General	Rapid
15	P	32	14.3 da	β	Excellent	Bone; general	Few weeks ¹
20	Ca	45	164 da	β	Moderate	Bone	Slow ¹
38	Sr	89	50.5 da	β	Excellent	Bone	Slow ¹
38	Sr	90	28 yr	β	Excellent	Bone	Very slow ¹
39	Y	91	57 da	β, γ	Poor ²	Bone	Very slow ¹
40	Zr	95	65 da	β, γ	Poor ²	Bone	Slow ¹
41	Nb	95	35 da	β, γ	Slight	Bone	Slow ¹
44	Ru	103	42 da	β, γ	Poor ²	Kidney	Few weeks
44	Ru	106	1 yr	β	Poor ²	Kidney	Few weeks
52	Te	127	90 da	γ	Moderate	Kidney	Few weeks
52	Te	129	32 da	γ	Moderate	Kidney	Few weeks
53	I	131	8.05 da	β, γ	Complete	Thyroid	Month
55	Cs	134	2.3 yr	β, γ	Complete	Muscle; general	Fairly rapid
55	Cs	137	30 \pm 3 yr	β, γ	Complete	Muscle; general	Fairly rapid
56	Ba	140	13 da	β, γ	Good	Bone	Very slow ¹
57	La	140	40 hr	β, γ	Poor ²	Bone; liver	Few weeks ^{1, 3}
58	Ce	139	140 da	γ (soft)	Poor ²	Bone; liver	Slow ^{1, 3}
58	Ce	141	32.5 da	β, γ	Poor ²	Bone; liver	Slow ^{1, 3}
58	Ce	144	282 da	β, γ	Poor ²	Bone; liver	Slow ^{1, 3}
59	Pr	143	13.8 da	β	Slight	Bone; liver	Slow ^{1, 3}
61	Pm	147	2.6 yr	β	Poor ²	Bone; liver	Slow ^{1, 3}
84	Po	210	138.3 da	α, γ	Good	Kidney	Slow
88	Ra	226	1620 yr	α, γ	Good	Bone	Almost nil ¹
92	U	238	4.51 $\times 10^9$ yr	α	Poor ²	Lung; kidney	Slow
94	Pu	239	2.44 $\times 10^4$ yr	α, γ	Very poor ²	Lung; bone	Almost nil ¹

/1/ Retention in bones is usually a matter of months, approaching a year or more in the case of Sr and Y, and becoming virtually permanent in case of Ra and Pu. /2/ Poorly absorbed isotopes, if in sufficient concentration, may damage the gastrointestinal tract during passage; they also tend to be retained in the lung if and when they gain access. /3/ Liver retention is about 10 days in experimental animals, and kidney retention about 20 days.

398. RADIOISOTOPES: POSSIBLE TELETHERAPY SOURCES

Teletherapy refers to therapeutic irradiation with collimated (parallel) gamma rays.

c = curie; Mev = million electron volts; n = neutron; r = roentgen.

Isotope			Half-life	Gamma Energy Mev	Practical Clinical Form	Production	Highest Practical- Volume Specific Activity ¹ c/ml	Specific Gamma Exposure Rate ² r/c-hr at 1 m
Z	Symbol	A						
88	Ra	226	1620 yr	0.2-2.2	Sulfate	Natural	4	0.84 ³
55	Cs	137	30 \pm 3 yr	0.661	Sulfate	Fission	100	0.39
63	Eu	152, 154	13, 16 yr	1.04	Oxide	Nuclear reactor	5000	0.70
27	Co	60	5.38 yr	1.17, 1.33	Metal	Nuclear reactor	1000	1.35
55	Cs	134	2.3 yr	0.5-1.3	Sulfate	Nuclear reactor	1000	1.20
58	Ce	144	282 da	0.6-2.6 ⁵	Oxide	Fission	2000	0.20
47	Ag	110	270 da	0.6-1.5	Metal	Nuclear reactor	250	1.40
69	Tm	170	129 da	0.08	Oxide	Nuclear reactor	500	0.01
73	Ta	182	115 da	0.04-1.2	Metal	Nuclear reactor	1500	0.6
21	Sc	46	85 da	0.9-1.1	Oxide	Nuclear reactor	500	1.1
65	Tb	160	72.5 da	0.1-1.1	Chloride	Nuclear reactor	50	0.3
77	Ir	192	74.4 da	0.1-0.6	Metal	Nuclear reactor	1000	0.3

/1/ One year irradiation in 5×10^{13} n/cm²/sec, 1 yr after removal from reactor, ideal geometry, for neutron reactions. /2/ Assuming that gamma absorption in the source is negligible. /3/ Assuming the source is sealed within a 0.5 mm-thick platinum capsule. /4/ Following filtration with 3 mm lead, 83% of total radiation appears to be from four high-energy photons averaging 1.08 mev. /5/ Gamma activity from 17 min praseodymium daughter; energy levels are doubtful.

399. RADIOISOTOPES PRODUCED BY THE CYCLOTRON

Adapted from National Bureau of Standards Handbook 52 "Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water," and from Nuclear Science & Engineering Corp. Catalogue.

Radioisotope	Half-life	Mode of Disintegration	Maximum Energy		Critical Organ weight, kg	Element Concentration g/kg	Daily Intake of Element	Use
			Beta, Mev	Gamma, Mev ¹				
1	Arsenic 73	76 da	K	0.011(X), 0.014, 0.052	Kidneys, 0.3			
2	Arsenic 74	17.5 da	β^- (30%); β^+ (35%); K (35%)	0.7, 1.4, 0.92, 1.53	Kidneys, 0.3			
3	Beryllium 7	54.5 da	K	0.00011(X), 0.48 (\sim 11%)	Bone, 7.0			
4	Cobalt 56	80 da	β^+ ; K	1.5	Liver, 1.7	2.0 $\times 10^{-4}$		Tracer studies.
5				0.0069(X), 0.511, 0.845, 1.26, 1.74, 2.01, 2.55, 3.25	Spleen, 0.15	4.7 $\times 10^{-4}$		
6	Cobalt 57	270 da	β^+	0.26	Liver, 1.7	2.0 $\times 10^{-4}$	Trace	
7				0.131, 0.511	Spleen, 0.15	4.7 $\times 10^{-4}$		
8	Cobalt 58	70 da	β^+ (14.5%), K	0.47	Liver, 1.7	2.0 $\times 10^{-4}$		
9				0.511, 0.81	Spleen, 0.15	4.7 $\times 10^{-4}$		
10	Gold 195	180 da	K	0.067(X)	Kidneys, 0.3		Trace	
11	Iron 55	2.94 yr	K	0.0064(X)	Blood, 5.0	0.5	12 mg	Blood studies; iron turn-over.
12	Manganese 52	6 da	β^+ (35%); K (65%)	0.582	Kidneys, 0.3	6.0 $\times 10^{-4}$		Tracer studies.
13				0.73, 0.94, 1.46	Liver, 1.7	1.7 $\times 10^{-3}$		
14	Manganese 54	310 da	K	0.0059(X), 0.835	Kidneys, 0.3	6.0 $\times 10^{-4}$	4 mg	
15					Liver, 1.7	1.7 $\times 10^{-3}$		
16	Sodium 22	2.6 yr	β^+	0.58	Total body, 70.0	1.5	4.0 g	Circulatory studies.
17	Strontium 85	65 da	K	0.014(X), 0.513	Bone, 7.0	6 $\times 10^{-2}$	0.3 mg	
18	Tungsten 181	140 da	K	0.058(X)	Bone, 7.0			
19	Zinc 65	250 da	β^+ (3%); K (97%)	0.32	Bone, 7.0	0.1	17 mg	Tracer studies.

/1/ (X) indicates K X-rays.

400. RADIOISOTOPES PRODUCED BY THE NUCLEAR CHAIN REACTOR

β^- = nuclear negatron; β^+ = nuclear positron; e^- = electron; K = electron capture from K ring; Mev = million electron volts; EC = electron capture.

		Maximum Energy of Radiation		Internal Dosages Determination				Investigative or Therapeutic Use
Isotope	Half-life	Beta	Gamma	Effective Energy per Disintegration Mev	Highest Isotope Concentration		Isotope Intake, per da	
					Mev	Mev			Tissue wt, kg^{1}	Isotope, g/kg tissue
1 Arsenic-76	26.8 hr	1.29, 2.49, 3.04	0.55, 1.20, 1.70	1.1	Kidneys, 0.3			Trace element metabolism.
2 Calcium-45	164 da	0.254		0.085	Bone, 7.0	150	800 mg	Muscle, bone metabolism.
3 Carbon-14	5570 yr	0.155		0.053	Adipose, 10	750	300 g	Protein, fat, carbohydrate, drug metabolism.
4 Chlorine-36	3.08 x 10 ⁵ yr	0.714		0.260	Total body, 70	1.5	6.7 g	Electrolyte balance.
5 Cobalt-60	5.38 yr	0.306	1.17, 1.33	0.72, 0.55	Liver, 1.7	2 x 10 ⁻⁴		External and interstitial radiotherapy.
6					Spleen, 0.15	4.7 x 10 ⁻⁴	Trace	Trace element metabolism.
7 Copper-64	12.84 hr	0.571 β^- , 0.657 β^+	1.35	0.11	Liver, 1.7	6 x 10 ⁻³	2 mg	Trace element metabolism.
8 Iodine-131	8.05 da	0.34, 0.61, 0.81, 0.25	0.64, 0.72, 0.36, 0.16, 0.28, 0.08	0.224	Thyroid, 0.02	0.52	0.2 mg	Thyroid function, iodine metabo- lism, determination of blood volume and brain tumors.
9 Iron-55	2.94 yr	EC		0.006	Blood, 5.0	0.5	12 mg	Iron, hemoglobin metabolism.
10 Iron-59	45 da	0.26, 0.46	1.10, 1.30	0.54	Blood, 5.0	0.5	12 mg	
11 Mercury-197	2.71 da	EC	0.08, 0.191					Distribution of mercurial diuretics.
12 Mercury-203	47 da	0.208	0.279					Therapy, diagnosis of blood dyscrasias; metabolism of nucleoproteins, phospho- lipids; phosphate tracers.
13 Phosphorus-32	14.3 da	1.701		0.68	Bone, 7.0	69	1.4 g	Mineral metabolism, electro- lyte balance.
14 Potassium-42	12.52 hr	2.04, 3.58	1.51	1.59	Muscle, 30.0	3	2.8 g	Hemodynamic function, min- eral metabolism, and electrolyte balance.
15 Sodium-24	15.1 hr	1.39	1.37, 2.75	2.7	Total body, 70	1.5	4.0 g	Metabolism and toxicity.
16 Strontium-89	50.5 da	1.46		0.55	Bone, 7.0	0.06	0.3 mg	External radiotherapy.
17 Strontium-90	28 yr	0.61		1.0	Bone, 7.0	0.06	0.3 mg	Metabolism of S-containing compounds.
18 Sulfur-35	87.1 da	0.167		0.055	Skin, 2.0	9	1.3 g	Protein, carbohydrate, fat metabolism.
19 Tritium (H-3)	12.4 yr	0.018		0.006	Total body, 70	100	250 g	Trace element metabolism.
20 Zinc-65	245 da	EC, 0.325 β^+	1.12	0.085	Bone, 7.0	0.1	17 mg	

^{1/1} Values for standard 70 kg man, determined at Chalk River Conference, Chalk River, Canada, September 29-30, 1949.

401. RADIATIONS: PHYSICAL PROPERTIES AND RELATIVE BIOLOGICAL EFFECTIVENESS

Radiation	Corpuscular ¹			Composition	RBE ³	Electromagnetic			RBE ³
	Physical Atomic Wt.	Mass g	Charge ²			Radiation	Wave Length ⁹ cm		
1 Alpha (α) ⁴	4.00275	6.6442 x 10 ⁻²⁴	2 ⁺	2 neutrons, 2 protons	20	9 Electric waves	6 x 10 ¹² to 1 x 10 ⁶		
2 Beta (β^- or β^+) ⁵	0.0005486	9.11 x 10 ⁻²⁸	1 ⁻ or 1 ⁺	Fundamental particle	1	10 Radio waves	5 x 10 ⁶ to 8 x 10 ⁻²		
3 Deuteron (d) ⁶	2.01418	3.3433 x 1	1 ⁺	1 neutron, 1 proton	~1	11 Infrared rays	3 x 10 ⁻² to 8 x 10 ⁻⁵		
4 Electron or negatron (e^-) ⁷	0.0005486	9.11 x 10 ⁻²⁸	1 ⁻	Fundamental particle	1	12 Visible light rays	8 x 10 ⁻⁵ to 4 x 10 ⁻⁵		
5 Positron (e^+)	0.0005486	9.11 x 10 ⁻²⁸	1 ⁺	Fundamental particle	1	13 Ultraviolet rays	4 x 10 ⁻⁵ to 8 x 10 ⁻⁷		
6 Proton (p) ⁸	1.00758	1.67 x 10 ⁻²⁴	1 ⁺	Fundamental particle	10	14 X-rays ¹⁰ (0.1 - 3.0 Mev)	2 x 10 ⁻⁶ to 3 x 10 ⁻¹⁰		1
7 Neutron (n), fast	1.00894	1.67 x 10 ⁻²⁴	Neutral	Fundamental particle	10	15 Gamma rays (γ) ¹⁰	2 x 10 ⁻⁸ to 6 x 10 ⁻¹¹		0.6-1
8 Neutron (n), slow	1.00894	1.67 x 10 ⁻²⁴	Neutral	Fundamental particle	5	16 Cosmic rays ¹¹	Variable		~1-10

^{1/1} Meson and neutrino are not included as they probably are unimportant biologically. ^{2/2} Unit charge = 4.8025 x 10⁻¹⁰ electrostatic units (esu), 1.60203 x 10⁻²⁰ electromagnetic units (emu). ^{3/3} Relative biological effectiveness, calculated as ratios of rep (roentgen equivalent physical), the amount of ionizing radiation from which tissue will absorb energy to the extent of 95 ergs/g (x-radiation = 1). ^{4/4} Helium nuclei. ^{5/5} The term "beta" (β) is reserved for electrons [negatrons (β^-) and positrons (β^+)] of nuclear origin. ^{6/6} Deuterium nuclei. ^{7/7} Electrons [negatrons (e^-)] of extra-nuclear origin, and cathode rays. ^{8/8} Hydrogen nuclei. ^{9/9} Approximate; some overlapping occurs. ^{10/10} x- and gamma ray (photons) mass units equal (0.00107 for 1 Mev). ^{11/11} Consist of electrons, protons, mesons, secondary pair production; below altitudes of 70,000 ft biological significance is questionable.

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402. RADIUM, COBALT-60, AND CESIUM-137 TELETHERAPY: PROTECTION REQUIREMENTS

For additional information, see National Bureau of Standards Handbook 54.

Part I: LEAD PRIMARY PROTECTIVE BARRIER REQUIREMENTS¹

PART II. LEAD PRIMARY PROTECTIVE SHIELDING REQUIREMENTS												
r/hr/m = roentgens per hour at 1 meter.												
Radium mg		Lead, in cm, Required at a Distance of:			Cobalt-60 r/hr/m	Lead, in cm, Required at a Distance of:			Cesium-137 r/hr/m	Lead, in cm, Required at a Distance of:		
		30 cm	1 m	2 m		30 cm	1 m	2 m		30 cm	1 m	2 m
48 hr/wk												
1	25	6.6	1.9	0	0.1	9.4	5.5	3.0	0.01	2.7	0.7	0
2	50	8.1	3.3	0.7	0.3	11.3	7.5	5.0	0.03	3.7	1.65	0.35
3	75	9.0	4.0	1.3	1.0	13.4	9.5	7.1	0.1	4.85	2.8	
4	100	9.6	4.6	1.9	3.0	15.4	11.4	9.0	0.3	5.9	3.8	
5	200	11.1	6.0	3.3	10.0	17.7	13.6	11.1	1.0	7.0	4.95	
12 hr/wk												
6	25	3.8	0	0	0.1	7.0	3.0	0.6	0.01	1.4	0	0
7	50	5.2	0.7	0	0.3	8.9	5.0	2.6	0.03	2.4	0.35	0
8	75	6.1	1.3	0	1.0	11.0	7.2	4.7	0.1	3.55	1.5	0.15
9	100	6.6	1.9	0	3.0	13.0	9.1	6.6	0.3	4.6	2.55	1.2
10	200	8.1	3.3	0.7	10.0	15.1	11.1	8.6	1.0	5.75	3.65	2.35
6 hr/wk												
11	25	2.5	0	0	0.1	5.8	1.8	0	0.01	0.8	0	0
12	50	3.8	0	0	0.3	7.7	3.9	1.3	0.03	1.75	0	0
13	75	4.6	0.3	0	1.0	9.7	5.9	3.5	0.1	2.95	0.9	0
14	100	5.2	0.7	0	3.0	11.7	7.8	5.4	0.3	3.95	1.9	0.55
15	200	6.6	1.9	0	10.0	13.9	10.0	7.5	1.0	5.05	3.0	1.7

^{1/1} Shielding required to reduce radiation exposure to 0.3 r/wk.

402. RADIUM, COBALT-60, AND CESIUM-137 TELETHERAPY: PROTECTION REQUIREMENTS (Concluded)

For additional information see National Bureau of Standards Handbook 54.

Part II: PROTECTIVE BARRIER REQUIREMENTS

Work load equal to 80,000 roentgens per week at 1 meter. r = roentgen; HVL = half-value layer.

For Primary-Protective Barrier										For Scattered Radiation ¹							
Distance (Source to Occupied Space)		Radium			Cobalt-60			Cesium-137			Distance (Scatterer to Occupied Space)		Radium and Cobalt-60		Cesium-137		
		Concrete cm	Steel cm	Lead cm	Concrete cm	Steel cm	Lead cm	Concrete cm	Steel cm	Lead cm			Concrete cm	Lead cm	Concrete cm	Lead cm	
1	3	9.8	108	34	23.1	96.5	32	19.2	76.2	27.7	9.6	3	9.8	30.2	1.8	24.9	0.9
2	3.1	10	106.7	34	23.1	96.5	32	19.2	76.2	27.7	9.5	3.1	10	27.4	1.8	24.6	0.9
3	4	13.1	101.6	32	21.6	91.4	30	18.2	73.7	27.7	9.0	4	13.1	24.4	1.5	21.8	0.7
4	4.6	15	99.1	31	20.9	88.9	29.5	17.6	71.1	23.1	8.8	4.6	15	22.9	1.4	20.3	0.7
5	5	16.4	96.5	30.5	20.4	87.6	29	17.4	69.9	22.6	8.6	5	16.4	21.8	1.3	19.3	0.6
6	6.1	20	92.7	29	19.3	83.8	27.4	16.6	66	21.6	8.2	6.1	20	19.8	1.1	17.5	0.5
7	7	23	90.2	27.9	18.6	81.3	26.4	16.1	64.8	21.1	7.9	7	23	18	1.1	16	0.5
8	7.6	25	87.6	27.4	18.1	80	25.9	15.7	63.5	20.8	7.8	7.6	25	17.3	0.9	15.2	0.4
9	8	26.3	87.6	27.4	17.9	78.7	25.9	15.6	63.5	20.1	7.7	8	26.3	16.5	0.8	14.5	0.4
10	9.2	30	85.1	26.4	17.2	77.5	24.9	15.1	58.4	19.8	7.5	9.2	30	15	0.7	13	0.3
11	10	32.8	82.6	25.9	16.8	74.9	24.4	14.8	57.2	19.3	7.3	10	32.8	14	0.7	12.2	0.3
12	Approximate HVL thickness		6.6	2.3	1.3	6.4	2.3	1.2	4.8	1.7	0.6	Approximate HVL thickness		4.1	3.3 ²	3.6	1.9 ²

/1/ Shielding required to reduce the 90° scattered radiation to 0.3 r/wk for a work load of 80,000 r/wk at 1 m and occupancy factor of 1 (full occupancy); the barrier for leakage radiation will depend upon the leakage permitted by the source housing. /2/ Values only for estimating purposes, since they vary considerably over the range of attenuations.

Part III: DISTANCE-EXPOSURE RELATIONSHIPS

Relation between distance and millicurie-hour for an exposure of 0.3 roentgen from an unshielded source.

Milli-curie hr	Distance to Source						Milli-curie hr	Distance to Source					
	Radium		Cobalt-60		Cesium-137			Radium		Cobalt-60		Cesium-137	
	ft	m	ft	m	ft	m		ft	m	ft	m	ft	m
1 10	0.5	0.15	0.7	0.21	0.4	0.12	5 1000	5.5	1.68	7.0	2.13	3.7	1.13
2 30	1.0	0.30	1.2	0.37	0.6	0.18	6 3000	9.5	2.90	12	3.66	6.5	1.98
3 100	1.8	0.55	2.2	0.67	1.2	0.37	7 10,000	18.0	5.48	22	6.71	12	3.66
4 300	3.0	0.91	3.8	1.16	2.1	0.64							

403. X-RADIATION: PROTECTION

For additional information, see National Bureau of Standards Handbooks 50 and 60.

concr = concrete; kv = kilovolt; kvp = kilovolt peak; ma = milliamperes.

Part I: PRIMARY PROTECTIVE BARRIER REQUIREMENTS

Target Distance	For 10 ma at Pulsating Potentials ¹ and Distances Indicated			For 400 kvp Pulsating Potential with Reflection Target			For 500 kv Constant Potential with Transmission Target			For 1000 kv Constant Potential with Transmission Target			For 2000 kvp Pulsating Potential with Transmission Target		
	75 kv			150 kv			250 kv			1 ma			5 ma		
	150 kv			250 kv			1 ma			5 ma			10 ma		
	250 kv			1 ma			5 ma			10 ma			20 ma		
	1 ma			5 ma			10 ma			20 ma			40 ma		
		Lead		Lead		Lead		Lead		Lead		Lead		Lead	
		mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
1	2	0.61	2.2	4.3	11.8										
2	3	0.91	2.0	4.0	10.9										
3	5	1.52	1.7	3.6	9.6	16.5	20.0	22.0	36	45.7	44	54.6	123	77.5	108.0
4	8	2.44	1.5	3.2	8.5	14.0	17.0	18.5	31	40.6	39	49.5	113	71.1	100.3
5	10	3.05	1.3	3.0	8.1	12.5	15.5	17.0	29	38.1	37	47.0	107	68.6	120
6	15	4.57	1.1	2.6	7.1	11.0	13.5	14.5	25	34.3	33	43.2	97	62.2	110
7	20	6.10	1.0	2.4	6.4	9.5	11.5	13.0	22	31.8	30	40.6	91	58.4	103
8	50	15.24	0.5	1.7	4.3	5.5	8.0	9.0	14	21.6	21	30.5	69	47.0	82
9	100	30.48							8	15.2	15	24.1	53	38.1	66
10	Approximate HVL thickness ³		1.8	0.3	0.8	2.0									
11	Radiation filter		0.5mm of Al	3.0mm of Al	3.0mm of Al	0.4mm of Sn, plus 0.75mm Cu and 2mm Al	2mm of W, plus 2.8mm Cu, 2.1mm brass, and 1.87mm of H ₂ O			2.8mm of W, plus 2.8mm Cu, 2.1mm of brass, and 18.7mm pf H ₂ O			1.6mm of W, plus 5.1mm Cu and 6.8mm of H ₂ O		

/1/ X-rays excited by direct current potentials require approximately 10% greater thickness. /2/ Density, 147 lb/cu ft. /3/ HVL = half value layer.

Part II: DISTANCE PROTECTION

Values are distances at which no shielding is necessary.

Target Current ma		values are distances at which no shielding is necessary.																			
		50 kvp		75 kvp		100 kvp		150 kvp		200 kvp		250 kvp		400 kvp		500 kvp		1000 kvp		2000 kvp	
		ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m	ft	m
1	0.005	15	4.57	20	6.10	25	7.62	20	6.10	25	7.62	25	7.62	25	7.62	30	9.14	90	27.43	195	59.44
2	0.01	20	6.10	25	7.62	30	9.14	30	9.14	35	10.67	35	10.67	35	10.67	40	12.19	115	35.05	240	73.15
3	0.025	30	9.14	40	12.19	45	13.72	45	13.72	50	15.24	55	16.76	55	16.76	60	18.29	175	53.34	370	112.78
4	0.05	40	12.19	50	15.24	60	18.29	60	18.29	65	19.81	70	21.34	70	21.34	75	22.86	220	67.06	460	140.21
5	0.1	50	15.24	70	21.34	80	24.38	80	24.38	90	27.43	95	28.96	95	28.96	110	33.53	275	83.82	540	164.39
6	0.25	70	21.34	95	25.91	115	35.05	115	35.05	125	38.10	135	41.45	135	41.45	155	47.24	380	115.82	720	219.46
7	0.5	85	25.91	115	35.05	145	44.20	145	44.20	165	50.29	170	51.82	170	51.82	200	60.96	460	140.21	850	259.08
8	1.0	100	30.48	145	44.20	180	54.86	185	56.39	205	62.48	215	65.53	215	65.53	255	77.72	550	167.64	980	298.70
9	2.0	115	35.05	175	53.34	220	67.06	225	68.58	255	77.72	270	82.30	270	82.30	320	97.54	640	195.07	1080	329.18
10	2.5	120	36.58	185	56.39	235	71.63	245	74.68	270	82.30	285	86.87	295	89.92	340	103.63	690	210.31		
11	5.0	140	42.67	220	67.06	280	85.34	295	89.92	330	100.58	350	106.68	360	109.73	410	124.97				
12	10.0	160	48.77	250	76.20	330	100.58	350	106.68	390	118.87	420	128.02								
13	15.0	175	53.34	270	82.30	355	108.20	390	118.37	430	131.06	460	140.21								
14	20.0	185	56.39	290	88.39	380	115.82	410	124.97	460	140.21	490	149.35								
15	25.0	195	59.94	300	91.44	390	118.87	420	128.02	480	146.30	510	155.45								

404. MAXIMUM PERMISSIBLE QUANTITY OF RADIOISOTOPES IN TOTAL BODY, AIR, AND WATER FOR CONTINUOUS EXPOSURE

Body intake is by ingestion and inhalation only. It is considered that any mixture of the radioisotopes listed is permissible, if the accumulated body burden in any organ, or the concentration in the contents of the gastrointestinal tract, does not reach a value that delivers a dose exceeding the maximum permissible dose-rate of 0.3 rem/wk. Explanations of the formulae and their use in calculating the values presented in this table may be obtained from Report of Subcommittee II on Permissible Dose For Internal Radiation, International Committee on Radiation Protection, and from Handbook 52 of the National Bureau of Standards.

A = mass number; α = alpha particles; β = beta particles; dr = daughter element; e⁻ = electron; γ = gamma rays; K = K type disintegration with a-ray emission; μ c = microcurie; rem = roentgen equivalent man; Z = atomic number; s. = soluble; i. = insoluble.

Radioisotope		Critical Organ ¹		Maximum Permissible Total Body Burden ²	Maximum Permissible Concentration		Radioisotope		Critical Organ ¹		Maximum Permissible Total Body Burden ²	Maximum Permissible Concentration	
Z Symbol A	Type of Decay	Organ	wt, kg	μ c	In H ₂ O	In Air	Z Symbol A	Type of Decay	Organ	wt, kg	μ c	In H ₂ O	In Air
1 H ³ (HTO or H ₂ O) ³	β^-	Total body	70	10,000	0.2	1×10^{-5}	53 57 La ¹⁴⁰	β^-, γ	Bone	7	0.3	0.3	4×10^{-7}
2 4 Be ¹⁴	K, γ	Bone	7	725	1.0	5×10^{-6}	54 58 Ce ¹⁴⁴ + Pr ¹⁴⁴	β^-, γ	Bone	7	1	8×10^{-3}	2×10^{-9}
3 6 C ¹⁴ = (CO ₂) ³	β^+	Fat	10	260	3×10^{-3}	1×10^{-5}	55 59 Pr ¹⁴³	β^-	Bone	7	6	8×10^{-2}	2×10^{-7}
4 9 F ¹⁸	β^+	Bone	7	5	0.2	3×10^{-5}	56 61 Pm ¹⁴⁷	β^-	Bone	7	25	0.2	4×10^{-8}
5 11 Na ²⁴	β^-, γ	Total body	70	15	8×10^{-3}	2×10^{-6}	57 62 Sm ¹⁵¹	β^-	Bone	7	90	5×10^{-2}	3×10^{-9}
6 15 P ³²	β^-	Bone	7	10	2×10^{-4}	1×10^{-7}	58 63 Eu ¹⁵⁴	β^-, γ	Bone	7	7	1×10^{-2}	2×10^{-9}
7 16 S ³⁵	β^-	Skin	2	300	5×10^{-3}	1×10^{-6}	59 67 Ho ¹⁶⁶	β^-, γ	Bone	7	4	5	8×10^{-7}
8 17 Cl ³⁶	β^-	Total body	70	230	4×10^{-3}	6×10^{-7}	60 69 Tm ¹⁷⁰	β^-, γ	Bone	7	4	6×10^{-2}	1×10^{-8}
9 18 Ar ⁴¹	β^-	Total body	70	33	5×10^{-4}	5×10^{-7}	61 71 Lu ¹⁷⁷	β^-, γ	Bone	7	18	6	1×10^{-6}
10 19 K ⁴²	β^-, γ	Muscle	30	21	1×10^{-2}	2×10^{-6}	62 73 Ta ¹⁸²	β^-, γ	Liver	1.7	6	1×10^{-1}	2×10^{-8}
11 20 Ca ⁴⁵	β^-	Bone	7	14	1×10^{-4}	8×10^{-9}	63 74 W ¹⁸¹	K, γ , e ⁻	Bone	7	24	0.1	5×10^{-6}
12 21 Sc ⁴⁶	β^-, γ	Spleen	0.15	6	0.4	7×10^{-8}	64 75 Re ¹⁸³	K, γ	Thyroid	0.02	37	9×10^{-2}	9×10^{-6}
13		Liver	1.7	5	0.3	5×10^{-8}	65		Skin	2	650	0.3	3×10^{-5}
14 21 Sc ⁴⁷	β^-	Spleen	0.15	15	4.0	9×10^{-7}	66 77 Ir ¹⁹⁰	β^-, γ	Kidneys	0.3	23	1×10^{-2}	8×10^{-7}
15		Liver	1.7	11	3.0	6×10^{-7}	67		Spleen	0.15	21	0.2	1×10^{-6}
16 21 Sc ⁴⁸	β^-, γ	Spleen	0.15	5	3.0	6×10^{-7}	68 77 Ir ¹⁹²	β^-, γ	Kidneys	0.3	3	9×10^{-4}	5×10^{-8}
17		Liver	1.7	3	1.0	3×10^{-7}	69		Spleen	0.15	3	6×10^{-3}	3×10^{-8}
18 23 V ⁴⁸	K, β^+, γ	Bone	7	10	0.3	6×10^{-5}	70 78 Pt ¹⁹¹	K, γ	Kidneys	0.3	2	6×10^{-3}	2×10^{-7}
19 24 Cr ⁵¹	K, γ	Kidneys	0.3	600	0.7	1×10^{-5}	71 78 Pt ¹⁹³	K, γ , e ⁻	Kidneys	0.3	3	5×10^{-3}	2×10^{-7}
20 25 Mn ⁵⁶	β^-, γ	Kidneys	0.3	25	0.15	4×10^{-6}	72 79 Au ¹⁹⁶	K, β^-, γ	Liver	1.7	8	5×10^{-2}	2×10^{-7}
21		Liver	1.7	8	0.4	4×10^{-6}	73		Kidneys	0.3	32	5×10^{-3}	2×10^{-7}
22 26 Fe ⁵⁵	K	Blood	5.4	1000	5×10^{-3}	7×10^{-7}	74 79 Au ¹⁹⁸	β^-, γ	Liver	1.7	3	4×10^{-2}	2×10^{-7}
23 26 Fe ⁵⁹	β^-, γ	Blood	5.4	13	1×10^{-4}	2×10^{-8}	75		Kidneys	0.3	10	3×10^{-3}	1×10^{-7}
24 27 Co ⁶⁰	β^-, γ	Liver	1.7	3	2×10^{-2}	1×10^{-6}	76 79 Au ¹⁹⁹	β^-, γ	Liver	1.7	9	9×10^{-2}	4×10^{-7}
25 28 Ni ⁵⁹	K	Liver	1.7	42	0.3	2×10^{-5}	77		Kidneys	0.3	30	8×10^{-3}	3×10^{-7}
26 29 Cu ⁶⁴	K, β^-, γ	Liver	1.7	120	6×10^{-2}	5×10^{-6}	78 81 Ti ²⁰⁰	K, γ , e ⁻	Muscle	30	40	2×10^{-2}	2×10^{-6}
27 30 Zn ⁶⁵	K, β^-, γ	Bone	7	400	6×10^{-2}	2×10^{-6}	79 81 Ti ²⁰¹	K, γ	Muscle	30	310	8×10^{-2}	7×10^{-6}
28 31 Ga ⁶⁷	β^-, γ	Bone	7	3	3	1×10^{-6}	80 81 Ti ²⁰²	K, γ , e ⁻	Muscle	30	230	2×10^{-2}	2×10^{-6}
29 32 Ge ⁷¹	K	Kidneys	0.3	72	10	4×10^{-5}	81 81 Ti ²⁰⁴	β^-	Muscle	30	200	8×10^{-3}	8×10^{-7}
30 33 As ⁷⁶	β^-, γ	Kidneys	0.3	11	0.2	2×10^{-6}	82 82 Pb ²⁰³	K, γ	Bone	7	61	0.1	7×10^{-6}
31 37 Rb ⁸⁶	β^-, γ	Muscle	30	64	3×10^{-3}	4×10^{-7}	83 82 Pb ²¹⁰ + dr ⁴	α, β^-, γ	Bone	7	0.2	2×10^{-6}	8×10^{-11}
32 38 Sr ⁸⁹	β^-	Bone	7	2	7×10^{-5}	2×10^{-8}	84 84 Po ²¹⁰ (s.)	α, γ	Spleen	0.15	0.04	3×10^{-5}	5×10^{-10}
33 38 Sr ⁹⁰ + Y ⁹⁰	β^-	Bone	7	1	8×10^{-7}	2×10^{-10}	85 84 Po ²¹⁰ (i.)	α, γ	Lungs	1	0.02	1×10^{-10}	
34 39 Y ⁹¹	β^-	Bone	7	3	4×10^{-2}	9×10^{-9}	86 85 At ²¹¹	α, K	Thyroid	0.02	0.001	3×10^{-6}	5×10^{-10}
35 40 Zr ⁹⁵ + Nb ⁹⁵	β^-, γ	Bone	7	10	0.4	8×10^{-8}	87 86 Ra ²²⁰ + dr	α, β, γ	Lungs	1		1×10^{-7}	
36 41 Nb ⁹⁵	β^-, γ	Bone	7	44	2×10^{-3}	2×10^{-7}	88 86 Ra ²²² + dr	α, β, γ	Lungs	1		1×10^{-7}	
37 42 Mo ⁹⁹	β^-, γ	Bone	7	17	5	6×10^{-4}	89 88 Ra ²²⁶ + 55% dr ⁴	α, β, γ	Bone	7	0.1	4×10^{-8}	8×10^{-12}
38 43 Tc ⁹⁶	K, γ	Kidneys	0.3	5	3×10^{-2}	3×10^{-6}	90 89 Ac ²²⁷ + dr ⁴	α, β, γ	Bone	7	0.01	3×10^{-6}	4×10^{-12}
39 44 Ru ¹⁰⁶ + Rh ¹⁰⁶	β^-, γ	Kidneys	0.3	4	0.1	3×10^{-8}	91 90 Th-natural	α, β, γ	Bone	7	0.01	5×10^{-7}	3×10^{-11}
40 45 Rh ¹⁰⁵	β^-, γ	Kidneys	0.3	9	0.4	2×10^{-6}	92 90 Th-natural (i.)	α, β, γ	Lungs	1	0.002	3×10^{-11}	
41 46 Pd ¹⁰³ + Rh ¹⁰³	K, e ⁻	Kidneys	0.3	7	1×10^{-2}	8×10^{-7}	93 90 Th ²³⁴ + Pa ²³⁴	β^-, γ	Bone	7	2	5×10^{-2}	1×10^{-8}
42 47 Ag ¹⁰⁵	K, γ	Liver	1.7	19	2	1×10^{-5}	94 92 U-natural (s.)	α, β^-, γ	Kidneys	0.3	0.04	1×10^{-4}	3×10^{-11}
43 47 Ag ¹⁰⁹	β^-	Liver	1.7	39	5	3×10^{-5}	95 92 U-natural (i.)	α, β^-, γ	Lungs	1	0.01	3×10^{-11}	
44 48 Cd ¹¹³ + Ag ¹⁰⁹	γ, K	Liver	1.7	45	7×10^{-2}	7×10^{-8}	96 92 U ²³³ (s.)	α, γ	Bone	7	0.04	1.5×10^{-4}	3×10^{-11}
45 50 Sn ¹¹³	γ, K	Bone	7	84	0.2	6×10^{-7}	97 92 U ²³³ (i.)	α, γ	Lungs	1	0.016	3×10^{-11}	
46 52 Te ¹²⁷	β^-, γ	Kidneys	0.3	4	3×10^{-2}	1×10^{-7}	98 94 Pu ²³⁹ (s.)	α, γ	Bone	7	0.04	6×10^{-6}	2×10^{-12}
47 52 Te ¹²⁹	β^-, γ	Kidneys	0.3	1.4	1×10^{-2}	4×10^{-8}	99 94 Pu ²³⁹ (i.)	α, γ	Lungs	1	0.02	2×10^{-12}	
48 53 I ¹³¹	β^-, γ	Thyroid	0.02	0.6	6×10^{-5}	6×10^{-9}	100 95 Am ²⁴¹	α, γ	Bone	7	0.06	2×10^{-4}	4×10^{-11}
49 54 Xe ¹³³	β^-, γ	Total body	70	320	4×10^{-3}	4×10^{-6}	101 96 Cm ²⁴²	α	Bone	7	0.06	1×10^{-3}	2×10^{-10}
50 54 Xe ¹³⁵	β^-, γ	Total body	70	100	1×10^{-3}	2×10^{-6}	102 Any fission mixture (β, γ) ⁵					1×10^{-76}	1×10^{-97}
51 55 Cs ¹³⁷ + Ba ¹³⁷	β^-, γ	Muscle	30	98	2×10^{-3}	2×10^{-7}	103 Any mixture of α -emitters ⁵					1×10^{-76}	5×10^{-128}
52 56 Ba ¹⁴⁰ + La ¹⁴⁰	β^-, γ	Bone	7	1	5×10^{-4}	2×10^{-8}							

/1/ Organ or tissue of body receiving the radioisotope that results in the greatest body damage. /2/ Exclusive of the amount in the gastrointestinal tract. /3/ Common body element. /4/ Values in μ c and μ c/ml given for parent element; daughter elements assumed to reach appropriate fraction of equilibrium with the parent after being taken into the body. /5/ Values for unidentified β^-, γ^- , and α -emitters for short periods of time (a few months). /6/ Safe for any mixture of β^- and γ^- emitters and all α -emitters except Ra²²⁶. /7/ Safe for any mixture of β^- and γ^- emitters except Sr⁹⁰. /8/ Safe for any mixture of α -emitters except Pu²³⁹ and Ac²²⁷.

405. MAXIMUM PERMISSIBLE EXTERNAL EXPOSURE OF BODY ORGANS TO IONIZING RADIATIONS: MAN, ADULT¹

Values may be converted from units of mrem/wk to mrad/wk by dividing by appropriate values of RBE (relative biological effectiveness). Commonly assumed average RBE values are: 1 for X, γ , β , e^- and e^+ ; 10 for p and α , and 20 for heavy ions (oxygen, carbon, nitrogen). Values in parentheses apply to persons over 45.

MeV = million electron volt; mr = milliroentgen; mrad = millirad; mrem = milliroentgen equivalent, man or mammal; rad = unit of energy absorption.

Type of Radiation	At Surface of Body Trunk	In Skin ^{2,3}		In Eye Lenses ⁵ mrem/wk	In Gonads ⁵ mrem/wk	In Blood-forming Organs ⁵ mrem/wk	In Intermediate Tissue ^{3,6} mrem/wk
		Total Body mrem/wk	Body Appendages ⁴ mrem/wk				
1 Low, penetrating ⁷	1500 mrad/wk	1500	1500	300	300	300	300-1500
2	(1500 mrad/wk)	(1500)	(1500)	(600)	(600)	(600)	(600-1500)
3 Roentgen (X) and	450 mr/wk	450	1500	450	300	400	400-450
4 gamma (γ) of	(900 mr/wk)	(900)	(1500)	(600)	(800)	(800)	(800-900)
5 Electrons (β^- , 6 e^- , e^+)	600 mrad/wk	600	1500	300	300	300	300-600
7 Protons (p)	(1200 mrad/wk)	(1200)	(1500)	(600)	(600)	(600)	(600-1200)
8	60 mrad/wk	600	1500	300	300	300	300-600
9 Fast neutrons	(120 mrad/wk)	(1200)	(1500)	(300)	(600)	(600)	(600-1200)
10 (n_f)	30-2000 n_t /sq cm/sec	300-600 ⁸	750-1500 ⁸	300	300	300	300-600
11 Thermal neutrons	(60-4000 n_t /sq cm/sec)	(600-1200) ⁸	(750-1500) ⁸	(300-600) ⁸	(600)	(600)	(600-1200)
12 (n_t)	3000 n_t /sq cm/sec	500 ⁸	1200 ⁸	300	100, 300 ^{8,9}	170 ⁸	170-500
13 Alpha particles	(6000 n_t /sq cm/sec)	(1000) ⁸	(1200) ⁸	(420) ⁸	(200, 600) ^{8,9}	(340) ⁸	(340-1000)
14 (α)	Exposure from internally deposited isotopes	1500	1500	300	300	300	300-1500
15 Oxygen, carbon, nitrogen, etc.	Generated in body by fast neutrons	(1500)	(1500)	(300)	(600)	(600)	(600-1500)
16		(1500)	(1500)	(300)	(600)	(600)	(600-1500)

/1/ Further information concerning data in this table may be obtained from Subcommittee 1, "Permissible Dose from External Sources," and Subcommittee 2, "Permissible Internal Dose," National Committee on Radiological Protection; also from Handbooks 52 and 59, National Bureau of Standards. /2/ Minimum thickness of epidermis taken as 0.07 mm. /3/ Values must not be used unless radiation is shielded or localized so that exposure limits to other critical tissues are not exceeded. /4/ Appendages include head, neck, hands, forearms, feet, and ankles. /5/ Average depths of lens, ovaries, testes, and blood-forming organs considered to be 3 mm, 7 cm, 1 cm, and 5 cm respectively. /6/ "Intermediate" tissue considered to be that of body trunk 0.07 mm-5 cm in depth (excluding testes and lens of eye). /7/ Low penetrating radiation (X, γ , β , e^- , e^+ or p) with a half-value layer of less than 1 mm of soft tissue; does not apply to neutron radiation. /8/ Values for neutron surface dose determined by pattern of distribution in body; values used decrease with energy of neutrons. /9/ Smaller value applies to ovaries at 7 cm depth, and larger value to testes at 1 cm depth.

406. BACKGROUND AND NON-OCCUPATIONAL EXPOSURES TO IONIZING RADIATION: MAN

β = beta ray; c = curie; μ = microcurie; r = roentgen; mr = milliroentgen; mrep = milliroentgen equivalent physical; μ g = microgram; γ = gamma ray.

Source	Amount or Rate	Source	Amount or Rate
1 Air, radon (incl. thoron)	$\sim 10^{-10}$ μ C/ml	18 Shoe fitting (20 sec exposure)	av. 10-15 r to feet
2 Airplane instruments (10-100 μ g per dial)		19 Spectacle lenses containing U	1-8 mr/hr β to eyes
3 At face of each dial	5-10 mr/hr	20 Water, drinking	10 ⁻¹⁶ -10 ⁻¹² c/ml
4 At pilot's position	<1 mr/hr	21 Water, sea	
5 "Background" exposure, average	0.4 mrep/da	22 K ⁴⁰	0.33 μ C/cu m
6 natural ¹	0.01-0.1 mr/hr	23 U	0.0015 mg/kg
7 C ¹⁴ (isotopic abundance 1.6×10^{-12})	16 dis./min/g carbon ²	24 Watch dial, wrist ($\sim 1 \mu$ g Ra)	~ 1 mr/hr, γ , wrist
8 Cosmic rays		25 X-ray, diagnostic ⁴	
9 Sea level	~ 0.1 mr/da	26 Abdomen ⁵	1.3 r
10 15,000 ft altitude	0.5 mr/da	27 Chest, photofluorographic	0.7-1.2 r
11 55,000 ft altitude	7.5 mr/da	28 Chest, plate 14 x 17 in.	0.05-0.25 r
12 Top of atmosphere	70.0 mr/da	29 Dental	0.5 r/film
13 Cow's milk	10 ⁻¹⁴ c/ml	30 Extremities	0.25-1.0 r
14 Earth's outer crust		31 Fluoroscopy	0.28 r/sec
15 Radium by weight	2×10^{-6}	32 Gastrointestinal series	0.65 r/plate
16 Thorium by weight	12 ppm	33 Lumbar spine, lateral ⁶	5.7 r
17 Uranium by weight	6 ppm	34 Pelvimetry, central area, antero-posterior films	0.2-0.4 r/film
18 Human body		35 Pregnancy, lateral	9.0 r
19 C ¹⁴ , total	0.0068 μ C	36 Skull	1.3 r ⁷
20 K ⁴⁰ , total	0.12 μ C	37 Urographic series, center of abdomen	1.3 r
21 Residual activity, all A-bomb detonations ³ calculated to July 15, 1952	8.8×10^{6c}		

/1/ Approximate total of cosmic ray and natural "background" 0.3 mr/24 hr. /2/ 16 disintegrations per min/g carbon. /3/ Includes suspended and deposited particles. /4/ Considerable variation depending on filtration distance and techniques. /5/ Abdominal fluoroscopy plus spot and serial films; 3 r in center of abdomen (may be higher). /6/ Up to 8 r in center of abdomen. /7/ Considerable variation depending on scope and type of examination.

407. HEAVY IONIZING PARTICLES: RELATIVE BIOLOGICAL EFFECTIVENESS VALUES

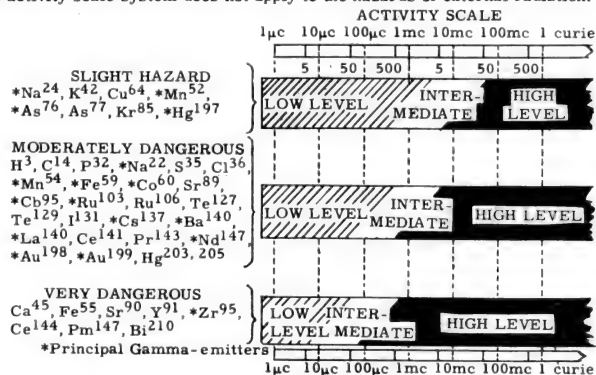
The following RBE values for all the critical organs, according to the value of the average specific ionizations (occurring in the critical organ in which it is highest) are recommended for determination of permissible tissue doses in rads from external sources by the relation: Permissible dose in rads = permissible dose in rems divided by RBE.¹

Average Specific Ionization ion pairs/ μ m ²	RBE	Average Linear Energy Transfer to H ₂ O kev/ μ m
1 100 or less	1	3.5 or less
2 100-200	1-2	3.5-7
3 200-650	2-5	7-23
4 650-1500	5-10	23-53
5 1500-5000	10-20	53-175

/1/ International Commission on Radiological Protection (1955). /2/ i.e., μ of path of H₂O.

408. RADIOISOTOPES, BODY ABSORPTION HAZARDS: MAN

These selected radioisotopes are grouped according to relative radiotoxicity, with the amounts considered as low, intermediate, or high level, in laboratory practice. The slant boundaries between levels indicate borderline zones and emphasize that there is no sharp transition between the levels and the associated protection techniques. This activity scale system does not apply to the hazards of external radiation.



409. IONIZING RADIATION EFFECTS: BIOLOGICAL TESTS

Data are approximate exposures for various biological effects. Exposure required for a specific test may vary with such biological factors as species, age, metabolic state, and with certain physical factors including temperature and oxygen tension.

α = alpha rays; β = beta rays; γ = gamma rays; n = n unit¹; x = roentgen - or X-rays

Exposure Level ²					Test Period ³	Test Material	Effect Observed
x	y	α	β	n			
1 8					24 hr	Grasshopper (neuroblast)	Reduced rate of mitosis.
2 15-500					10 da	Frog (sperm)	Abnormal development (5-100%).
3 20-600	20-600				1-28 da	Mouse (testis)	Damage to germinal cells.
4 30-800					5 da	Mouse (thymus)	Weight loss.
5 35-225					2 hr-4 da	Mouse (skin)	Cells in mitosis decreased.
6	36-540			6-150	1.5-48 hr	Rat (retina)	Inhibition of mitosis.
7 50					10 min	Carboxypeptidase (dilute)	30% inactivation.
8 50					12 da	Salamander (eggs)	LD ₅₀ .
9 50					21 da	Grasshopper (eggs, 6 da old)	LD ₅₀ (or abnormal development, 50%).
10 50-110					18 hr	Bluebottle fly (eggs)	LD ₅₀ .
11 100					24 hr	Chick (fibroblast culture)	Death of cells at next division.
12 100-600					3-10 da	Mouse (blood)	Decreased number of cells.
13 100-1000					7 da	Frog (eggs, fertilized)	Inhibition or abnormality of development.
14 125					21 da	Grasshopper (eggs, 1 da old)	LD ₅₀ (or abnormal development, 50%).
15 140	250	36			1-14 da	Broad bean (root)	Inhibition of growth (cell division).
16 175-250	310		7750		14 da	Guinea pig ⁴	LD ₅₀ .
17 190	240		275	85	48 hr	Fruit fly (eggs)	LD ₅₀ (failure to hatch).
18 200					24 hr	Thymus (cell suspension)	Death of cells (eosin staining).
19 300-350					30 da	Dog	LD ₅₀ .
20 320					5 da	Tradescantia (microspores)	Chromosome breaks (17.3%).
21 350					30 da	Goat	LD ₅₀ .
22 350					2 wk	Fruit fly (adult)	1% increase in sex-linked mutations.
23	375-3600				2 wk	Fruit fly	Increased recessive mutation rate.
24 400 ⁵					30 da	Man	LD ₅₀ (estimated).
25 400					24 hr	Spleen (cell suspension)	Death of cells (eosin staining).
26 400					15 da	Chick embryo (50 hr incubation)	Death of embryo.
27 400-500 ⁶					30 da	Swine	LD ₅₀ .
28 400-600 ⁷	850-950	4700		200-400	30 da	Mouse	LD ₅₀ .
29 500					100 hr	Wheat seedling (root, 18 hr old)	50% decrease in growth rate (longitudinal).
30 500					30 da	Monkey	LD ₅₀ .
31 600-900	1270	7500		200-300	30 da	Rat	LD ₅₀ .
32 670					30 da	Goldfish	LD ₅₀ .
33 700					6 wk	Frog	LD ₅₀ .
34 725 ⁸					30 da	Hamster	LD ₅₀ .
35 800				175-400	30 da	Rabbit	LD ₅₀ .
36 800 ⁹					12 da	Chicken	LD ₅₀ .
37 1000					4 da	Ascaris (eggs)	LD ₅₀ .
38 1000					3 wk	Duckweed	50% decrease in growth rate of fronds.
39 1000-2000					100 hr	Tomato, lettuce (germinated)	Inhibition of linear growth of shoot.
40 1000-2000					1 yr	Pigeon (<15 da old)	Inhibition of growth of wing bone.
41 1100					70 hr	Wheat seedling (primary leaf)	50% decrease in growth rate (longitudinal).
42 1500					30 da	Turtle	LD ₅₀ (estimated).
43 2000					1 wk	Fundulus (eggs, gametes, embryo)	Abnormal development of embryo.
44 2500					100 da	Salpiglossis	50% decrease in growth rate; repression of flowering.
45 2,500-10,000					3 hr	Chick (fibroblast culture)	Immediate death of cells.
46 3000					30 da	Triton (salamander)	LD ₅₀ (estimated).
47 3,000-50,000					2 wk	Neurospora (ascospores)	Production of biochemical mutants.
48 5,000-60,000					10 da	Mouse sarcoma 180	Inhibition of growth in transplants.
49 5600				2500	24 hr	Escherichia coli	LD ₅₀ .
50 10,000-100,000					10-40 da	Trypanosoma cruzi	Decreased infective power.
51 10,000-120,000					3-10 da	Tobacco callus (tissue culture)	Inhibition of growth.
52 15,000					32 da	Rabbit (mesenteric lymph node)	Inhibition of cell migration.
53 30,000					2 hr	Arbacia (eggs)	Delay of cleavage.
54 30,000					1 hr	Yeast cells	Immediate death.
55 40,000					5 hr	Frog (sperm)	Incomplete inactivation. ¹⁰
56 50,000					24 hr	Rhizopus nigricans (spores)	50% less germination than controls.
57 94,000					3 wk	Chaetomium globosum (spores)	Lethal mutants in 50%.
58 100,000					10 min	Carboxypeptidase (concentrated)	30% inactivation.
59 150,000				37,000	24 hr	Bacillus mesentericus (spores)	LD ₅₀ .
60 180,000					30 hr	Penicillium (spores)	50% less germination than control.
61 200,000					40 da	Grasshopper embryo	Depression of respiration.
62 200,000					18 hr	Escherichia coli (phage C36)	37% inactivation.
63 210,000					18 hr	Lily (pollen grains)	50% less germination than control.
64 300,000-600,000					45 min	Pandorina	Immediate death.
65 330,000					2 hr	Colpidium colpoda	LD ₅₀ .
66 350,000					10-15 min	Paramecium caudatum	Immediate loss of motility.
67 430,000	370,000	1900			5 da	Tobacco mosaic virus	37% inactivation.

/1/ One n unit = quantity of fast neutron radiation that will discharge a particular Victoreen ionizing chamber in the same magnitude as will one r of X-rays. Measurements have indicated that one n unit is approximately equivalent to 2.5 rep. /2/ Exposure levels for x- or gamma (γ) radiation in r (roentgens); all other exposures in rep (roentgen equivalent physical). /3/ Test period = time after irradiation when effect was observed. /4/ Hybrids are more radio-resistant. /5/ Whole body, hard X-rays. However, detectable biological changes occur at levels of 25r-35r. /6/ LD₅₀ also reported as 400-450r. /7/ LD₅₀ also reported as about 625r, with range of 400-700r. /8/ LD₅₀ also reported as 800r. /9/ LD₅₀ for 30-da exposure for chicken depends upon age, but is estimated at 800-1000r. /10/ Sperm in testes can be used to fertilize eggs, even after testes have been exposed to 120,000r.

410. IONIZING RADIATION EFFECTS: BIOLOGICALLY IMPORTANT COMPOUNDS¹

d = deuterons; e = electrons; n = neutrons; r = roentgens; α = alpha particles; β = beta particles; γ = gamma rays.

Material	Radiation	Dose	Intensity	Effect or Product	Molecules/100 ev
Acids					
1 C _n H _{2n} + 1 COOH (n = 1-29)	α (Rn)			CO ₂ .	0.5-2.8
2				CO.	<0.5
3				H ₂ .	<0.4
4				H ₂ O.	0.9-2.5
5				C _n H _{2n} +2.	0.4-1.1
6 Formic (aqueous)	e (1.4 Mev)			Loss of acid function.	2.5
7	d (4 Mev)			Loss of acid function.	1.7
8	γ (Co ⁶⁰)		5 x 10 ⁴ r/hr	CO ₂ .	4.1
9				H ₂ .	0.5
10				H ₂ O ₂ .	4.6
11 Acetic (aqueous, deaerated, 1 M) ²	He ⁺⁺ (35 Mev) ³	3.8 x 10 ²⁰ ev/ml	0.2 μa	CO ₂ .	0.28
12				Succinic acid.	0.32
13				CH ₄ .	0.08
14	d (18 Mev)	3.8 x 10 ²⁰ ev/ml	0.2 μa	CO ₂ .	0.39
15				Succinic acid.	0.59
16				CH ₄ .	0.11
17 Caprylic (liquid)	α (Rn)			H ₂ , CO ₂ , CO, H ₂ O, CH ₄ , C ₂ H ₆ , C ₃ H ₈ , C ₄ H ₁₀ .	
18 Lauric (solid)	α (Rn)			H ₂ , CO ₂ , CO, H ₂ O, n-C ₁₁ H ₂₄ .	
19 Palmitic (solid)	α (Rn)			H ₂ , CO ₂ , CO, H ₂ O, n-C ₁₅ H ₃₂ .	
20 Glycolic, Ca salt (solid)	β (C ¹⁴)	1.75-2.54 x 10 ⁷ r		Decomposition.	31-77
21 Oxalic (aqueous)	X (2.5 Mev)	~ 10 ⁶ r		Loss of acid function.	4-6
22 Lactic (aqueous)	X	1.2 x 10 ⁴ r		Pyruvic acid.	
23 Benzoic (aqueous)	X (220 kv)	10 ⁴ -10 ⁵ r	2350 r/min	o-C ₆ H ₄ (OH) COOH.	1.0
24				m-C ₆ H ₄ (OH) COOH.	
25				p-C ₆ H ₄ (OH) COOH.	
Alcohols, Thiols					
26 Methanol (liquid)	β (C ¹⁴)	5.94 x 10 ⁸ r		Decomposition.	12
27	He ⁺⁺ (27 Mev) ³		1.9-3.9 x 10 ²¹ ev/sec	H ₂ .	3.4-4.1
28	He ⁺⁺ (27 Mev) ³		1.9-3.9 x 10 ²¹ ev/sec	HCHO.	1.7
29 Ethanol (liquid)	He ⁺⁺ (27 Mev) ³		1.3-5.1 x 10 ²¹ ev/sec	H ₂ .	1.8-3.2
30				CH ₃ CHO.	0.7-1.7
31				(CH ₂ OH) ₂ .	0.7-1.1
32 Sucrose (solid)	X			Inversion, red color.	
33 Sucrose (aqueous)	X			Inversion.	
34 Propane-1,3-dithiol (aqueous)	X (250 kv)	500-5000 r		Oxidation.	11
35 2,3-Dimercapto-1-propanol (BAL)(liquid)	X (250 kv)	500-5000 r		Oxidation.	11
Vitamins and Related Compounds					
36 o-Aminobenzoic acid (aqueous)	e (3 Mev)			Decarboxylation, loss of amine function.	
37 p-Aminobenzoic acid (aqueous)	e (3 Mev)			Decarboxylation, loss of amine function.	
38 β-Carotene (petroleum ether)	X (3 Mev)	0.66 x 10 ⁶ r		Decomposition.	0.16
39 Choline chloride (solid)	β (C ¹⁴)	1.07 x 10 ⁷ r		Decomposition.	490
40 Niacin (aqueous)	e (3 Mev)	0.17-5.28 x 10 ⁶ r		Decarboxylation.	1.6
Amino Acids					
41 Glycine (aqueous)	X (200 kv)		3500 r/min	H ₂ , NH ₃ , HCHO (trace).	Non-linear
42	X (500 kv)	1.66 x 10 ⁵ r		NH ₃ .	< 9.1
43	β (n a) Li	8-20 x 10 ²⁰ ev/ml		NH ₃ .	< 1.7
44 Alanine (aqueous)	X (220 kv)		3500 r/min	H ₂ , NH ₃ , CH ₃ CHO (trace).	Non-linear
45 Serine (aqueous)	X (200 kv)		3500 r/min	H ₂ , NH ₃ , (CHO) ₂ , HOCH ₂ CHO.	Non-linear
46 L-Serine (aqueous)	X	1.66 x 10 ⁵ r		NH ₃ .	1-13
47 Valine-HCl (solid)	β (C ¹⁴)	8.2 x 10 ⁶ r		Decomposition.	0.3
48 Norvaline-HCl (solid)	β (C ¹⁴)	4.03 x 10 ⁷ r		Decomposition.	1.7
49 Norleucine (solid)	β (C ¹⁴)	3.2 x 10 ⁶ r		Decomposition.	10
50 Cysteine (aqueous)	X (250 kv)		10 ³ r/min	Loss of thiol function.	6-26
51				H ₂ O ₂ .	0-7
52				H ₂ S.	~1 (aerated)
53				H ₂ S.	2.5-5 (deaerated)
54 Histidine-HCl (aqueous)	e (3 Mev)	10 ⁵ - 10 ⁶ r		Decomposition.	1.0-10
Steroids					
55 Cholesterol (aqueous)	X (200 kv)		3000 r/min	Cholestane-3(β), 5(α), 6(β)-triol; 3(β)-hydroxycholesterol-5-en-7-one.	
56 Δ ⁵ -Pregnen-3-(β)-ol-20-one (aqueous)	X (200 kv)		3000 r/min	3(β), 5(α), 6(β)-Trihydroxyallopregnan-20-one.	
57 Cholic acid (aqueous)	X (220 kv)	1.8 x 10 ⁶ r		3(α), 12(α)-Dihydroxy-7-ketocholelanic acid.	
58 (+)-Estrone-b (aqueous)	X (200 kv)	10 ⁶ r		A lactone.	
Miscellaneous					
59 Desoxyribonucleic acid (aqueous)	X (200 kv)		3000 r/min	NH ₃ .	0.4
60				Inorganic phosphate.	0.003
61 Yeast ribonucleic acid (aqueous)	X (200 kv)		3000 r/min	NH ₃ .	0.4
62				Inorganic phosphate.	0.01
63 Sodium thymonucleate (aqueous)	X (0.2, 2 Mev)			Decomposition.	
64	γ (Ra, Co ⁶⁰)			Decomposition.	~0.06
65 Carboxypeptidase (aqueous)	α (Rn)			Inactivation.	0.03
66	X (500 kv)			Inactivation.	0.55
67 Ferricytochrome c (aqueous)	X (180-200 kv)		439-1700 r/min	Oxidation.	1.7
68 Glutathione (aqueous)	X (250 kv)	500-5000 r		Oxidation.	10

/1/ In all aqueous media radiolysis may yield H₂, H₂O₂, and O₂, dependent on conditions; such data are not included here. /2/ Data for aerated solution are more complex. /3/ Rays of artificial (cyclotron) origin.

411. ULTRAVIOLET RADIATION EFFECTS: BIOLOGICALLY IMPORTANT COMPOUNDS

Substance ¹	Irradiation	Products or Results of Irradiation	Quantum Efficiency moles/Einstein ²
Amino Acids and Amines			
1 L-Alanine	Hg-lamp	L-Lactic acid, pyruvic acid, NH ₃ .	0.027
2 Aminoisobutyric acid	Hg-lamp	NH ₃ + (?)	
3 L-Aspartic acid	Hg-lamp	L-Malic acid.	
4 Betaine	Hg-lamp	Trimethylamine.	0.02
5 Cysteine	Hg-lamp	Cystine + (?)	
6 Cystine	2250Å	Cysteine + (?)	0.02
7 Dihydroxyphenylalanine (dopa)	Hg-lamp	Unknown.	
8 Glycine	2265Å	Glycolic acid, NH ₃ , CO.	0.033
9 Histamine	Hg-lamp	Unknown.	
10 Histidine		Imidazol-acetaldehyde, NH ₃ , hydroxy acid, histamine (?).	
11 Homocystine	Hg-lamp	S-Benzylhomocystine.	
12 Leucine	Hg-lamp	NH ₃ + (?)	
13 Methionine	2250Å	Methylmercaptan.	
14 Phenylalanine	Hg-lamp	NH ₃ , modified phenyl group, tyrosine.	
15 Proline, hydroxyproline	Hg-lamp	Destruction.	
16 Tryptophan	Hg-lamp	Indole-3-acetic acid + (?); change in absorption spectrum.	
17 Tyrosine	Hg-lamp	Unknown; some dopa; change in absorption spectrum.	
18 Valine	Hg-lamp	NH ₃ + (?)	
Hemipeptides ³			
19 Acetylalanine	2537Å	NH ₃ + (?)	0.072
20 Acetyltryptophan	2537Å	Modified indole group; no tryptophan.	
21 Benzoylalanine	2537Å	Alanine, modified phenyl group.	0.0027
22 Benzylstearylamine	2483Å, 2537Å	Stearic acid, benzylamine.	
23 Phenylacetylalanine	2537Å	Alanine, modified phenyl group.	0.0064
24 Phenylbutyrylalanine	2537Å	Alanine, modified phenyl group.	0.055
25 β-Phenylethylstearylamine	2483Å, 2537Å	Stearic acid, β-phenylethylamine.	
26 Phenylpropionylalanine	2537Å	Alanine, modified phenyl group.	0.0041
27 Phenylvalerylalanine	2537Å	Alanine, modified phenyl group.	0.0034
28 Propionylphenylalanine	2537Å	NH ₃ , modified phenyl group.	0.005
29 Stearic anilide	2350Å, 2400Å	Stearic acid, aniline.	0.26
Peptides			
30 Acetylalanylglycine	Hg-lamp	NH ₃ + (?)	
31 Alanylglycine	Hg-lamp	NH ₃ + (?)	
32 Glycylleucine	Hg-lamp	NH ₃ + (?)	
33 Glycyltryptophan		Modified indole group; no amino acids.	
34 Glycyltyrosine	2537Å	Modified phenyl group; no amino acids.	0.0034
35 Gramicidin		Destruction.	
36 Leucyltyrosine		Modified phenyl group; no amino acids.	
Purines and Derivatives			
37 Adenine	2537Å	NH ₃ , urea; loss of characteristic absorption spectrum.	
38 Adenosine	2537Å	NH ₃ , urea; loss of characteristic absorption spectrum.	
39 Adenosinetriphosphate	<3000	Adenine.	
40 Adenylic acid	2537Å	NH ₃ , urea; pentose destruction; loss of characteristic absorption spectrum.	
41 Diphosphopyridine nucleotide(DPN)	<3000	Adenine; adenylic acid, adenosine diphosphate, nicotinamide; loss of coenzyme function.	
42 Triphosphopyridine nucleotide(TPN)	2537	Adenosine 2', 5'-diphosphate, 2'-phospho-adenosine diphosphate, nicotinamide.	
43 Guanine, guanosine, guanylic acid, hypoxanthine, inosine, uric acid, xanthine, xanthosine	2537Å	NH ₃ , urea; loss of characteristic absorption spectra; uric acid also yields triuret.	
Pyrimidines and Derivatives			
44 Cytidine		NH ₃ , urea; loss of characteristic absorption spectrum; pentose of cytidylic acid destroyed.	
45 Cytidylic acid			
46 Cytosine		6- or 5-Hydroxy-1, 3-dimethylhydouracil.	
47 1, 3-Dimethyluracil		NH ₃ , urea; loss of characteristic absorption spectrum.	
48 Thymine		NH ₃ , urea; loss of characteristic absorption spectrum. (Primary product reverts to uracil in acid. Change in absorption spectrum, oxamide and parabanic acid.)	
49 Uracil	2537Å		
50 Uridine		NH ₃ , urea; loss of characteristic absorption spectrum. (Primary product reverts to uridine in acid.)	
51 Uridylic acid		Unknown product which reverts to uridylic acid in acid solution.	0.0216
Nucleic Acids			
52 Desoxyribonucleic acid	2537Å	Depolymerization and destruction of pyrimidine bases; loss of characteristic absorption spectrum and liberation of inorganic phosphate.	10 ⁻⁶ (depolymerization)
53 Desoxyribonucleic acid	2650Å	Gel formation.	0.01-0.04(dry)
54 DNA (transforming principle)		Inactivated by 500 ergs/sq mm per 200 μg DNA.	
55 Ribonucleic acid	2537Å	Depolymerization; loss of characteristic absorption spectrum.	0.1 (depolymerization)
Vitamins			
56 B ₁ (2-methyl-5-ethoxymethyl-6-aminopyrimidine component)	2537Å	Loss of selective absorption and ability to support growth of <i>Phycomyces blakesleeana</i> .	0.0184
57 B ₁ (4-methyl-5-β-hydroxyethyl-thiazole component)	2537Å	Loss of ability to support growth of <i>Phycomyces</i> ; changes in side groups, breakdown of ring.	0.347
58 Ergosterol	2536Å, 2800Å	Vitamin D.	0.2-0.3
Enzymes and Related Proteins ³			
59 Aldolase		Loss of hexose diphosphate activity.	0.0019
60 Antibody, bushy stunt virus			0.00096
61 Antibody, clover nodule bacteria	2537Å	Reduction in flocculation of antigen.	0.0024
62 Antibody, tobacco mosaic virus			0.00096
63 Carboxypeptidase		Loss of chloroacetyltyrosinase activity.	0.001
64 Catalase		Loss of hydrogen peroxidase activity.	0.0011(dry)

/1/ In aqueous solution, unless otherwise indicated. /2/ Equivalent to number of molecules reacting per number of quanta absorbed. /3/ Values are representative and usually vary with pH. Absolute value depends on assumed molecular weight.

411. ULTRAVIOLET RADIATION EFFECTS: BIOLOGICALLY IMPORTANT COMPOUNDS (Concluded)

Substance ¹		Irradiation	Products or Results of Irradiation	Quantum Efficiency moles/Einstein ²
Enzymes and Related Proteins ³ (concluded)				
65 Chymotrypsin	2537Å 2967Å - 2301Å	2537Å	Loss of activity on casein. Inability to convert to chymotrypsin. Loss of nuclease activity. Inability to produce hypoglycemic convulsions in mice. Loss of Micrococcus lysodeicticus activity. Loss of trypsin-inhibiting power. Loss of hemoglobinase activity. Loss of nuclease activity. Loss of effect on diphosphopyridine nucleotide. Loss of caseinase activity. Loss of trypsin-inhibiting activity.	0.0065
66 Chymotrypsin				0.008-0.002(dry)
67 Chymotrypsinogen				0.0011(dry)
68 Desoxyribonuclease				0.0039(dry)
69 Insulin				0.015
70 Lysozyme				0.24
71 Pancreatic trypsin inhibitor				0.031
72 Pepsin				0.0024
73 Ribonuclease				0.03
74 Triosephosphate dehydrogenase				0.003
75 Trypsin	1860Å 2537Å 3130Å	Loss of urease activity	0.018	
76 Trypsin			0.02-0.1(dry, 90°-450°K)	
77 Trypsin inhibitor, soybean			0.0088	
78 Urease			0.00938	
79 Urease	2537Å 3130Å	Loss of urease activity	0.00093	
80 Urease			0.00816	
Viruses and Phages ³				
81 Tobacco mosaic virus	2537Å	Virus sensitized to heat, suffers loss of infectivity for Nicotiana glutinosa.	4.3 x 10 ⁻⁵	
82 T ₁ phage	2220Å	Loss of activity on Escherichia coli, strain B.	5.0 x 10 ⁻⁴	
83 T ₁ phage	2537Å		6.3 x 10 ⁻⁴	
84 T ₁ phage	3022Å		7.3 x 10 ⁻⁴	
85 T ₂ phage	2220Å		2.7 x 10 ⁻⁴	
86 T ₂ phage	2537Å		3.1 x 10 ⁻⁴	
87 T ₂ phage	3022Å		1.8 x 10 ⁻⁴	

/1/ In aqueous solution, unless otherwise indicated. /2/ Equivalent to number of molecules reacting per number of quanta absorbed. /3/ Values are representative and usually vary with pH. Absolute value depends on assumed molecular weight.

412. ULTRAVIOLET RADIATION: LD₅₀ FOR SOME UNICELLULAR ORGANISMS

Values in parentheses are ultraviolet wave lengths in mμ.

Organism	Ultraviolet Wave Length, mμ							
	(310)	(302)	(297)	(290)	(280)	(265)	(254)	(248)
LD ₅₀ Dose, ergs/sq mm								
Bacteria ²								
1 Escherichia coli	4580		2965	339	181-225	104	44-208	172(270)
2 Micrococcus candicans		11,375	3775		295	212	341	
3 Pseudomonas pyocyanea			7150		320	234	291	
4 Staphylococcus aureus		3000	500	200	110-440	90-206	86-275	96
5 Serratia marcescens			677		47	49	57	
6 Salmonella typhi-murium	5556				237			
Fungi								
7 Saccharomyces cerevisiae, in dark		23,500			556-1260	457-863	503-900	696
8 in light							1400	
9 Neurospora crassa, microconidia, in dark		1050			496	300	370	
10 in light							1020	
11 Neurospora crassa, macroconidia, in dark					1700	1120	1440	
12 in light							3000	
Protozoa								
13 Amoeba proteus, in dark							2160	
14 Paramecium aurelia, in dark					3000			
15 in light					6000			
Protophyta								
16 Chlorella pyrenoidosa, in dark							30,000	

/1/ Sterilizing dose, or dose which prevents colony formation under the usual conditions for culture of the organism. /2/ Not specified whether bacteria were handled in the light or dark.

413. IRRADIATION: LATE EFFECTS

Ranges, when preceded by average values, are given in parentheses.

c = curie; mc = millicurie; μ c = microcurie; ev = electron volt; Mev = million electron volts; kv = 1000 volts; n = n unit¹; r = roentgen; rep = roentgen equivalent physical; rem = roentgen equivalent mammals; α = alpha rays; γ = gamma rays.

Type		Radiation	Amount	Latent Period	Late Effects
				Man	
1	A-bomb	Epilation dose		2 yr	10 cases of A-bomb cataract Japan, 1 case USA.
2	Hiroshima	Irradiated in utero, 1st half of pregnancy		5 yr	Microcephaly and mental retardation were present in 7 of 11 children within 1200 m of hypocenter.
3	Japan	Area within 2000 m of hypocenter		3-5 yr	Leukemia incidence 9.3 times that of non-exposed population of Hiroshima and Nagasaki (only 1948-50 incl.).
4		Area within 1000 m of hypocenter		3-5 yr	Leukemia incidence 32 times that of non-exposed population (only 1948-50 incl.).
5	Cyclotron	Epilation dose		2 yr	2 cases of cyclotron-induced cataract.
6	16 Mev neutrons, fast	400-500 n		2 mo-5 yr	Severe epidermolytic reaction (13/16), skin atrophy and fibrosis, persistent ulcerations, and diminished repair by normal tissues; radiation osteitis; severe bowel reactions.
7	0-20 Mev neutrons, fast (small γ components)	10-135 n		2-10 yr	Cataracts: severe(3/10), slight to moderate(4/10), minimal (3/10); chronic irradiation: no blood changes; 2 cases mild epilation.
8	Radium-226 (external)	1000-1500 mg-hr			Cessation of ovarian function, 77% (63/82).
9		1500-2000 mg-hr			Cessation of ovarian function (6/7).
10	Radium ²	0.02-0.5 μ g	residual (ingested)	14-48 yr	Radiation osteitis (25%).
11		0.5-2.0 μ g		23.6 yr (1-32) yr	Osteomyelitis and loss of teeth (5/9); radiation osteitis (8/9); pathol. fractures (3/9); giant cell tumor (1/9); osteogenic sarcoma (1/9); epidermoid carcinoma nasopharynx (1/9); high incidence of deafness and arthritis.
12		2.7 μ g		24.6 (8-32) yr	Osteomyelitis of jaw and loss of teeth (5/9); radiation osteitis (8/9); pathol. fracture (1/9); fibrosarcoma (1/9); epidermoid carcinoma nasopharynx (1/9).
13		2-20 μ g		6-8 yr	Radiation osteitis (osteosclerosis); osteogenic sarcoma (5/18 deaths); pathological fractures.
14		8-23 μ g		19.5 (7-21) yr	Osteomyelitis of jaw and loss of teeth (6/8); radiation osteitis (7/8); epidermoid carcinoma nasopharynx (1/8); osteogenic carcinoma (1/8); pathol. fractures (3/8); leukemia (1/8).
15		10-180 μ g		1-8 yr	Anemia with hyperplastic marrow, jaw necrosis (13 cases).
16		100-800 μ g orig. dose, 1.0-10 μ g residual radium		20-30 yr post treatment	Changes in bone density, similar to those in dead or dying bone, in all patients having at least 1 μ g residual Ra; minimal changes with 0.5 μ g (24 cases); dental changes in all with at least 4 μ g residual Ra. Greatly enlarged haversian canals; distortion of normal bone configuration (7/24), edentia, mandibular lesions (3/19), aseptic necrosis of bone (7/24), fibrosarcoma, honey-combed teeth, "pink tooth."
17	Uranium, radium ores	Variable doses		13-23 yr	Lung cancer in uranium miners of Joachimsthal and Schneeberg.
18	X-ray	Variable doses		months to years	Skin atrophy, telangiectasis, sclerosis, pigmentation, alopecia and altered vasomotion, diminished sweat and sebaceous function; loss of cutaneous ridges and finger prints; ulcers and keratoses; malignancies; hyperkeratotic, warty growths; deformed and brittle, dry nails, loss of nails, fissures, subungual hyperkeratoses.
19		100-300 r (200 and 1000 kv)		60-680 da	Temporary drop in white blood cell count.
20		500-624 hr		100-600 da	Temporary macrocytic anemia.
21		625 r (to ovaries)			94% castrated.
22		\leq 1000 r (to center of vertebrae)		Followed 13 yr post-treatment	Permanent cessation of menstruation, 72 patients.
23		1000-2000 r (to spine)		Followed 3-7 yr	Vertebrae normal (irrespective of child's age); determined on 45 individuals, 34 living patients, 11 at autopsy.
24		1500-8500 r, therapeutic dose, eye tumor		2 yr	"Transverse-line" growth disturbance of vertebrae (irrespective of child's age up to 6 yr).
25		1500-25,000 r (130-200 kv)		6-22 yr	7 cases of cataract.
26		1700-3000 r (half value layer 1.5 mm Cu), lower abdomen		6-18 mo	11 cases osteogenic sarcoma.
27		About 2000 r (to spine)		Followed 2-13 yr	Nephrosclerosis; hypertension; elevated albuminuria (22/55); edema; anuria. Death from congestive heart failure and/or uremia (7/55); (over 2300 r there is high risk of renal failure).
28		3500-5000 r		8-28 mo	Contour irregularity of vertebrae (all children, except one 1 yr old).
29	X-ray, radium	4000-6700 r		8.6 (5-20) yr	Lens opacities (4 cases).
					Sarcoma; osteogenic sarcoma. Therapy for lupus vulgaris, papillomata of bladder, actinomycosis, tubercular psoriasis.
30	X-ray and radium equipment	Unknown			Leukemia in radiologists (4.68%), 9 times the incidence in non-radiological physicians (0.51%).

/1/ One n unit defined as the quantity of fast neutron radiation that discharges a particular 100 r Victoreen ionizing chamber in the same magnitude as does one γ of X-radiation. Measurements have indicated that one n unit is the approximate equivalent of 2.5 rep. /2/ Variable amounts of mesothorium also present with the radium in some instances.

413. IRRADIATION: LATE EFFECTS (Continued)

Ranges, when preceded by average values, are given in parentheses.

c = curie; mc = millicurie; μ c = microcurie; ev = electron volt; Mev = million electron volts; kv = 1000 volts; n = n unit¹; r = roentgen; rep = roentgen equivalent physical; rem = roentgen equivalent mammals; α = alpha rays; γ = gamma rays.

		Radiation		Latent Period		Late Effects	
Type		Amount		Dog			
31	Neutrons	0.012, 0.06, 0.11 n/day	1 yr	Reduction of lymphocytes only observed effect (6 doses/wk). Mucoid conjunctivitis, keratoconjunctivitis and corneal opacities; reduced size of spleen and testes; increased incidence of infection; hypoplasia of bone marrow and regional lymph nodes; hemorrhage of lymph nodes, heart, stomach, small bowel and kidney; reduction of lymphocytes, neutrophils and erythrocytes. Destruction and chronic inflammation of cornea and changes in lens capsules and fibers, but no cataracts. Cataracts in 65-75% of animals. Lowered sperm count, increase in abnormal sperm. Lowered sperm count, increase in abnormal sperm. Partial testicular atrophy; slight reduction of leucocytes; Lymphopenia. } If irradiation is stopped after 1 yr, there is partial recovery 100% aspermic; neutrophil dec. of sperm 4 mo later in the 1 r/da group. Severe injury of testes. Lymphocyte and platelet reduction. 50% aspermic. Severe injury of testes. Lymphocyte, platelet, and erythrocyte depression. 50% aspermic. Bone marrow hypoplasia; focal bowel and lymph node hemorrhages. 50% survival.			
32		1.7 n/da	1 yr				
33	Neutrons, fast	150 n	2 yr				
34		800-900 n	2 yr				
35	X-ray	0.1 r/da (6 times/wk)	2 yr				
36		0.5 r/da	11 mo				
37		0.5 r/da	2 yr				
38		1.0 r/da	6 mo				
39		1.0 r/da	9 mo				
40		1.0 r/da	1 yr				
41		1.0 r/da	2 yr				
42		3.0 r/da	2 mo				
43		6.0 r/da	9 mo				
44		6.0 r/da	1.5 yr				
45		10.0 r/da	2 mo				
46		10.0 r/da	3.5 mo				
47		10.0 r/da	1.5 yr				
48		10.0 r/da	6 mo				
Guinea Pig							
49	Cobalt-60 (γ -rays), external	15 r/da	106 da	50% survival.			
50		30 r/da	63 da	50% survival.			
51		60 r/da	41 da	50% survival.			
52		90 r/da	20 da	50% survival.			
53		120 r/da	18 da	50% survival.			
54	Phosphorus-32	7750 rep (external)	2 mo	Alopecia.			
55	Radium, filtered (γ -rays), repeated low dose	Non-irradiated (controls)	38 mo	75% survival.			
56		0.11 r/da	38 mo	75% survival.			
57		1.1 r/da (1050 r)	32 mo	50% survival.			
58		2.2 r/da (2100 r)	32 mo	50% survival.			
59		4.4 r/da (2400 r)	18 mo	50% survival; reduction white blood cells.			
60		8.8 r/da (2300 r)	5 mo	50% survival; recurrent anemia.			
Mouse							
61	Cobalt-60 (γ -rays), external	90 r/da	52 da	50% survival.			
62		115 r/da	37 da	50% survival.			
63		140 r/da	22 da	50% survival.			
64	Neutrons, fast, 10^3 ev to ≥ 4 Mev, and γ -rays (divided doses)	Non-irradiated (controls)	51 wk	50% survival for controls and each dosage increment. With respect to shortening life span, 1 n (divided small doses) is equivalent to 35 r. (For acute killing 1 n is equivalent to 9 r). Threshold for shortening life span is about 1 r/da and less than 0.1 n.			
65		1 r/da	61 wk				
66		8.6 r/da	48 wk				
67		Non-irradiated (controls)	70 wk				
68		0.115 n/da (total 32.2 n)	40 wk				
69		1.15 n/da (total 241.5 n)	30 wk	50% survival for controls and each dosage increment. Terminal changes are generalized; atrophy and an increased incidence of mediastinal lymphomatosis.			
70		4.3 n/da (total 301 n)	10 wk				
71		13 n/da (total 273 n)	3 wk				
72	Neutrons, fast, and X-rays (single exposure)	Non-irradiated (controls)	64 wk				
73		500 r	58 wk				
74		700 r	39 wk	Lens opacities, 92% at 22 wk ³ . Lens opacities, 91% at 18 wk ³ . Lens opacities, 100% at 11 wk ³ . General epilation, skin atrophy, loss of ear tips, ulcerations, keratosis. Lens opacities (4000 r). Lens opacities (3000 r). Tumors; shortening of life span. Osteogenic sarcoma. Marked shortening of life span. Increased osteogenic sarcoma. Marked shortening of life span; debilitation and increased incidence of infection.			
75		26 n	52 wk				
76		50 n	48 wk				
77		78 n	42 wk				
78		90 n	6 wk				
79	Neutrons, thermal	51 rem	14 wk				
80		196.6 rem	14 wk				
81		477 rem	6 wk				
82	Phosphorus-32	3000-4000 rep (external)	30 da				
83		3000-4000 rep (external)	3-4 mo				
84		3000-4000 rep (external)	8 mo				
85		3000-4000 rep (external)	6-8 mo				
86	Plutonium-239	3.1-15.6 μ c/kg (i. v.)	190-250 da				
87		> 6.1 μ c/kg (i. v.)					
88	Radium-226	> 12 μ c/kg (i. v.)	250-300 da				
89		> 50 μ c/kg (0.6-4170 μ c/kg, i. v.)					

/1/ One n unit defined as the quantity of fast neutron radiation that discharges a particular 100 r Victoreen ionizing chamber in the same magnitude as does one r of X-radiation. Measurements have indicated that one n unit is the approximate equivalent of 2.5 rep. /3/ n/X-ray relative biological effectiveness (RBE) for production of opacities is 9 times the n/X-ray RBE for 30 da lethality.

413. IRRADIATION: LATE EFFECTS (Continued)

Ranges, when preceded by average values, are given in parentheses.

c = curie; mc = millicurie; μ c = microcurie; ev = electron volt; Mev = million electron volts; kv = 1000 volts; n = n unit¹; r = roentgen; rep = roentgen equivalent physical; rem = roentgen equivalent mammals; a = alpha rays; γ = gamma rays.

Radiation		Latent Period	Late Effects
Type	Amount		
Mouse (concluded)			
90	Radium filtered (γ -rays), repeated low dose	Non-irradiated (controls)	50% survival for controls and each dosage increment; increase in lymphatic leukemia, mammary and ovarian carcinoma.
91		1.1 r/da (760 r)	
92		2.2 r/da (1390 r)	
93		4.4 r/da (2640 r)	
94		8.8 r/da (4400 r)	
95	Strontium-89 (β -rays) Monthly injections	0.05 $\mu\text{c/g}$	Bone tumors begin to develop.
96		0.1 $\mu\text{c/g}$	
97		0.2 $\mu\text{c/g}$	
98		0.5 $\mu\text{c/g}$	
99		0.1 $\mu\text{c/g}$	
100	Single injection	2.5 $\mu\text{c/g}$	Osteogenic sarcoma (probably significant); used 0.1-10.0 $\mu\text{c/kg}$. Osteogenic sarcoma (probably significant); used 0.1-100 $\mu\text{c/kg}$. Osteogenic sarcoma. Shortening of life span. Possibly significant increase in osteogenic sarcoma. At birth severe skeletal and other abnormalities, with clearly defined critical periods.
101		5.0 $\mu\text{c/g}$	
102	Uranium-232	0.1-1.0 $\mu\text{c/kg}$ (i. v.)	
103		> 1.0 $\mu\text{c/kg}$ (i. v.)	
104	Uranium-233	2.5 $\mu\text{c/kg}$ (i. v.)	
105		> 5 $\mu\text{c/kg}$ (i. v.)	
106		> 53 $\mu\text{c/kg}$ (i. v.)	
107	Uranium-238	> 3.6 $\times 10^{-7}$ $\mu\text{c/kg}$ (i. v.)	
108	X-ray	25-200 r to fetus early in pregnancy (equivalent to 2-6 wk, human)	Until birth
109		Irradiation of fetus late in pregnancy (equivalent to after 6 wk, human)	Until birth
110		50 r (250 kv)	17 wk
111		200 r (250 kv)	14 wk
112		500 r (250 kv)	6 wk
113		400 r (single dose)	15-23 mo
114		600-1200 r (divided doses)	9-14 mo
115		600-1200 r (divided doses)	6-12 mo
116		600 r (120 kv, 150 r alternate wks, to whole body)	420-580 da
117		600 r (120 kv, 150 r alternate wks, to whole body, mediastinum shielded)	118-525 da
118		1200 r (120 kv, 300 r alternate wks, to upper half of body)	324-365 da
119		1200 r (120 kv, 300 alternate wks, to alternate halves of body)	420-508 da
120		Non-irradiated (controls)	526-570 da
Rabbit			
121	Neutrons	0.012 n/da, 6 doses/wk	1 yr
122		0.06 n/da, 6 doses/wk	1 yr
123		0.11 n/da, 6 doses/wk	1 yr
124		1.7 n/da	1 yr
125		3.7 n/wk (52.7-83.7 n, total)	4-12 mo
126		33-100 n (single doses)	2-5 mo
127	Fission	3 $\times 10^{10}$ particles/ml	125 da
128	14 Mev	8 $\times 10^9$ particles/ml	125 da
129	Phosphorus-32 (external)	2500-3000 rep	2 mo
130		5000 rep	
131		7500 rep	
132		15000 rep	
133	Radium	100 μg in 90 da (RaSO_4 in glycerine, orally)	2 mo
134			5-18 mo
135			9 mo
136	Thorium dioxide ("thorotrast"), 20% colloidal suspension (α - and γ -rays)	I.v. injection	
137	X-ray	0.1-0.5 r/da	1 yr
138		1.0 r/da	1 yr
139		10 r/da	8 wk
140			3 mo
141			1 yr
142		250 r or less (1.2 Mev)	150 da
143		500 r	125 da

^{1/1} One n unit defined as the quantity of fast neutron radiation that discharges a particular 100 r Victoreen ionizing chamber in the same magnitude as does one r of X-radiation. Measurements have indicated that one n unit is the approximate equivalent of 2.5 rep. ^{3/3} n/X-ray relative biological effectiveness (RBE) for production of opacities is 9 times the n/X-ray RBE for 30 da lethality.

413. IRRADIATIONS: LATE EFFECTS (Concluded)

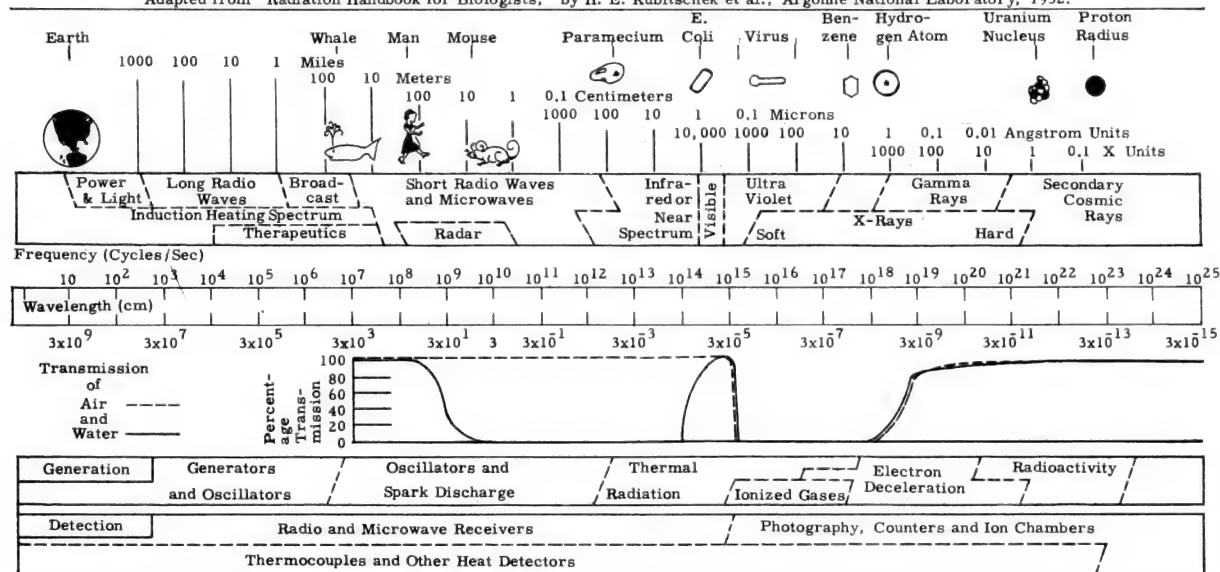
Ranges, when preceded by average values, are given in parentheses. c=curie; mc=millicurie; μ c=microcurie; ev=electron volt; Mev=million electron volts; kv=1000 volts; n=n unit¹; r=roentgen; rep=roentgen equivalent physical; rem=roentgen equivalent mammals; α =alpha rays; γ =gamma rays.

Type	Radiation	Amount	Latent Period	Late Effects
Rat (concluded)				
144	Cerium-144	1-3 mc/kg	200 da	Osteogenic sarcoma; liver atrophy with ascites and jaundice.
145	Cobalt-60 (γ -rays), external	20 r/da	332 da	50% survival; increased tumor frequency.
146		60 r/da	236 da	50% survival; increased tumor frequency.
147		70 r/da	72 da	50% survival; increased tumor frequency.
148		80 r/da	53 da	50% survival; increased tumor frequency.
149		90 r/da	48 da	50% survival; increased tumor frequency.
150	Neutrons	120 r/da	38 da	50% survival; increased tumor frequency.
151		0.012-0.06 n/da	1 yr	No effects observed.
152		0.11 n/da	1 yr	Number of neoplasms three times that of controls (including leukemias).
153		1.7 n/da	1 yr	Incr. infection and incidence of neoplasms (high leukemia incidence); bilateral cataracts; hypoplasia of spleen; atrophy of testes and ovarian follicles; early reduction of lymphocytes; reduction of erythrocytes.
154	Phosphorus-32	4000-5000 rep (external)	4-5 mo	Tumors; keratoses; lens opacities (low incidence); ulceration of scrotum and base of tail; alopecia.
155	Praesodmium-144	1-3 mc/kg	200 da	Osteogenic sarcoma; liver atrophy with ascites and jaundice.
156	Plutonium-239	0.02 μ g/g (0.0031-0.0062 c/g)	300-400 da	Osteogenic sarcomas.
157		0.03 μ c/g	3-7 mo	Areas of dead bone and calcified cartilage, resumption of normal bone growth at epiphysis; destruction of spermatogenic cells; atrophy of ovary.
158	Radium	0.125 μ c/g	5 mo	Damage to epiphyseal cartilage, overgrowth with atypical bone, loss of normal bone cells; atrophy of ovary.
159		0.5 μ c/g	3-6 mo	Degenerative changes in ovary; damage to blood vessels.
160		0.6 μ c/g	5 mo	Damage to epiphyseal cartilage and marrow, production of abnormal bone.
161	Strontium-89	0.05 μ c/g	500 da	Osteogenic sarcomas.
162		0.1 μ c/g	400 da	
163		0.5 μ c/g (single injection)	400 da	
164		1.0 μ c/g level (monthly injections)	250 da	
165		5.0 μ c/g (single injection)	200 da	
166	Thorium dioxide ("thorotrast"), 20% colloidal suspension (α - and γ -rays)	0.3 ml	14 mo	Produced fibroblastic tumors (14/60).
167		2.5 ml	10-17 mo	Produced sarcoma (33/60).
168		5.0 ml	10-17 mo	Produced sarcoma (50/50).
169		0.1 r/da (total 49 r)	81.7 wk	50% survival.
170		0.5 r/da (total 230 r)	76.7 wk	50% survival; incr. infibro-adenomata of mammary gland.
171	X-ray	1.0 r/da (total 460 r)	76.9 wk	50% survival.
172		10.0 r/da (total 3500 r)	58.3 wk	50% survival; increase in leukemia.
173		12.5-100 r (8th da of gestation)		Retardation of growth.
174		12.5-100 r (9th and 10th da of gestation)		Malformations; increased mortality; growth retardation.
175		375 r (and above, whole body)		Enamel hypoplasia, retarded enamel dentin formation
176		500 r (whole body)		5 mo. required for complete restoration of epithelium in testes (Vanderbilt's strain adult males).
177	Yttrium-91	2000 r (and above, locally)	1-3 mo	Retardation of eruption of incisors.
178		4000 r (locally to teeth)		Stoppage of growth of dentin (lengthwise) in incisors.
179		2.0 μ c/g		Damage to epiphyseal cartilage and production of a typical bone; increase in spleen hematopoiesis.
180		20-30 mc/kg (1 dose orally), or 1-2 mc/kg/da, 6 da/wk for 3 mo		A variety of intestinal lesions with obstruction. Y is essentially non-absorbed from the intestinal tract.

1/1 One unit defined as the quantity of fast neutron radiation which will discharge a particular 100 r Victoreen ionizing chamber by the same amount as will one r of X-rays. Measurements have indicated that one n unit equals approximately 2.5 rep.

414. RADIATION: SUMMARY OF SOME PHYSICAL CHARACTERISTICS

Adapted from "Radiation Handbook for Biologists," by H. E. Kubitschek et al., Argonne National Laboratory, 1952.



415. FACTORS AFFECTING RESPONSE TO X- AND GAMMA RADIATION

+ = increased; - = decreased; ± = no effect; i.p. = intraperitoneal; i.v. = intravenous.

Part I: PROPHYLACTIC FACTORS

Grouping of agents or measures is tentative and arbitrary as there is no general agreement concerning mechanism of action. Contradictory or conflicting results under similar conditions represent data reported by different investigators. Although there may be differences in the efficacy of the agents, it is not always possible to grade their effects on survival.

Agent or Condition ¹	Animal	Time of Administration ² (With Respect to Irradiation)	Survival	Other Effects
Hypoxia (Physical)				
1 Anemia, bleeding-induced	Rat	Immediately before.		- sensitivity of skin and of Jensen rat sarcoma.
2 Anemia, bleeding-induced	Dog, rat	Immediately before or after.		Stimulation of erythropoiesis.
3 Carbon dioxide atmosphere	Mouse(newborn)	Immediately before and during.	+	
4 Hypothermia	Mouse(newborn)	Immediately before and during.	+	
5 Hypothermia	Rat(newborn)	Immediately before and during.		- skin sensitivity.
6 Interference with respiration ³	Rat(newborn)	Immediately before and during.		
7 Lowered ambient oxygen tension	Mouse	Immediately before and during.	+	- incidence of abnormal mitoses in bone marrow.
8 Lowered ambient oxygen tension	Mouse	Immediately before and during.		No protection vs induction of dominant lethal mutations.
9 Lowered ambient oxygen tension	Rat	Immediately before and during.	+	
10 Lowered ambient oxygen tension	Mouse(in utero)	Immediately before and during.		- developmental abnormalities.
11 Nitrogen atmosphere	Mouse(newborn)	Immediately before and during.	+	
Hypoxia (Chemical)				
12 p-Aminopropiophenone	Rat, mouse	Immediately before.	+	
13 p-Aminopropiophenone	Rat	Immediately before or after.		Stimulation of erythropoiesis.
14 Carbon monoxide (inhalation)	Mouse	Immediately before and during.	+	
15 Epinephrine	Rat	Immediately before.	+	
16 Hydrogen sulfide (inhalation)	Mouse	Immediately before and during.	+	
17 Methylene blue	Mouse	Immediately before.	+	
18 Morphine	Mouse	Immediately before.	+	
19 Pitressin	Rat	Immediately before.	+	
20 Sodium nitrite	Mouse	Immediately before.	+	
Bone Marrow Hyperplasia				
21 Bleeding	Rabbit	Several da before.		+ resistance of erythropoietic tissue.
22 Cobalt	Mouse	Fed in diet several da before.	+	
23 Estrogens	Mouse	5 to 15 da before.	+	
24 High altitude (simulated)	Mouse	Repeatedly several da before.		+ resistance of erythropoietic tissue.
25 High altitude (simulated)	Rat	Repeatedly several da before.	-	- protection of DNA synthesis in bone marrow and spleen.
26 Phenylhydrazine	Rabbit	Repeatedly several da before.	+	+ resistance of erythropoietic tissue.
Amines ⁴				
27 Glucosamine	Mouse	Immediately before.	+	
28 Hydroxylamine	Mouse	Immediately before.	+	
29 5-Hydroxytryptamine	Rat	Immediately before.	+	
30 Isopropylamine	Mouse	Immediately before.	+	
31 Methylamine	Mouse	Immediately before.	+	
Sulfhydryl Compounds ⁵				
32 2-Aminoethyl disulfide	Mouse	Immediately before.	+	
33 Cysteine	Mouse	Immediately before.	+	- leukopenia, - splenic atrophy.
34 Cysteine	Mouse	Immediately before.		Additive with hypoxia in reducing incidence of abnormal mitoses in marrow.
35 Cysteine	Rat	Immediately before.	+	- depression and more rapid recovery of WBC and RBC.
36 Cysteine	Rabbit	Immediately before.		- incidence of nuclear fragmentation in ocular lens epithelium.
37 Cysteine	Rabbit	Immediately before ⁶		- histological damage to cornea following beta radiation.
38 2,3-Dimercapto-1-propanol(BAL)	Rat, mouse	Immediately before.	+	
39 Glutathione	Mouse, rat	Immediately before.	+	No difference in initial destructive effects of radiation but more rapid recovery of hematopoietic and lymphopoietic tissues.
40 β-Mercaptoethylamine ⁷	Mouse	Immediately before.	+	More rapid recovery of white blood cell count; no protection against mutagenic effects.
41 β-Mercaptoethylamine	Rat	Immediately before.	+	Prevented radiation-induced increase in adrenal weight and late fall in adrenal cholesterol.
42 Monothiol glycerol	Mouse	Immediately before.	+	
43 Sodium ethanedithiophosphonate	Mouse	Immediately before.	+	
44 Thiosorbitol	Mouse	Immediately before.	+	
45 Thiourea	Mouse	Immediately before.	+	
Miscellaneous				
46 Atropine	Mouse	Daily before and after.	+	
47 Carbamoylcholine chloride	Mouse	Immediately before.	+	
48 Ethanol	Mouse	Immediately before.	+	
49 Glycerol	Mouse	Immediately before.	+	
50 Malononitrile	Mouse	Immediately before.	+	
51 Mecholyl bromide or chloride	Mouse	Immediately before.	+	
52 Propylene glycol	Mouse	Immediately before.	+	
53 Serum, foreign	Mouse	10 days before.	±	
54 Serum, foreign	Rabbit	10 days before.		- severity of skin reaction.
55 Serum, foreign	Dog	7 days before.		- leukopenia, + general health.
56 Serum or plasma ⁸	Mouse	Immediately before.	±	
57 Sodium azide	Mouse	Immediately before.	+	
58 Sodium or potassium cyanide	Mouse	Immediately before.	+	
59 Sodium or potassium cyanide	Rat	Immediately before.	±	
60 Terramycin	Rat	Repeatedly for 48-72 hr before.	+	

/1/ Unless otherwise indicated, chemical agents given by parenteral injection. /2/ "Immediately before" indicates a few minutes to 1 hour previous to radiation exposure. /3/ Taping of chest. /4/ Do not contain sulfhydryl groups. /5/ Some of these agents do not contain the sulfhydryl group, but it is believed that in vivo a sulfhydryl linkage is encountered; for instance, 2-aminoethyl disulfide (cystinamine) is converted in vivo to β-mercaptoethylamine (cysteamine). /6/ Local administration. /7/ The mercaptoethylamine derivative β-aminoethylisothiouranium is somewhat less toxic to mice, and more stable than its parent compound. /8/ Homologous or heterologous.

415. SOME FACTORS AFFECTING RESPONSE TO X- AND GAMMA RADIATION (Concluded)

+ = increased; - = decreased; ± = no effect; i.p. = intraperitoneal; i.v. = intravenous.

Part II: THERAPEUTIC FACTORS

Agent	Animal ¹	Method of Administration	Effect on Survival
Antibiotics			
1 Aureomycin	Mouse, rat, guinea pig, dog	Daily by various routes and dosage schedules.	± to slight +.
2 Streptomycin	Mouse	Daily injections, various dosages.	Significant +.
3 Streptomycin	Swine	Daily injections after combined X-ray exposure and thermal burns.	+
4 Terramycin	Mouse, rat	Various dosages, dosage schedules, methods of administration.	± to slight +.
5 Terramycin	Dog	Orally, 100 mg/kg/da for 28 da.	+
6 Antibiotics, wide variety, various combinations	Mouse, rat, guinea pig	Various routes, dosages, dosage schedules.	± to slight +.
Transfusion of Blood and Various Blood Components			
7 Blood, whole	Dog	Exchange transfusion ² within a few hr.	± to slight +.
8 Blood, whole	Dog	Repeated transfusions.	±.
9 Blood, whole, plus aureomycin	Dog	Repeated transfusions plus aureomycin in various dosage schedules.	±.
10 Leukocytes	Dog	Daily transfusion of leukocyte suspensions.	Survival data inadequate; leukocytes migrate to foci of infections.
11 Platelets	Dog	Repeated transfusions of platelet suspensions	Survival data inadequate; control of hemorrhages.
Spleen and Bone Marrow Inoculations			
12 Spleen	Mouse, rat	Implant, or i.p. injection of homologous homogenate within a few min to 2 da. ⁴	Marked + (mouse spleen); ± (rat spleen).
13 Spleen	Mouse	Implants to anterior chamber of eye.	+
14 Marrow, bone	Mouse, rat	I.p. inoculation of homologous marrow within a few min to 2 da.	Marked +.
Miscellaneous			
15 Bone	Mouse	I.p. inoculation of ground bone 1-2 hr.	±.
16 Parabiosis	Rat	Para-biotic union of normal and irradiated rats within a few hr to several da.	±.
17 Properdin	Mouse, rat	I.v. injection.	±, if any.

/1/ Animals exposed to total-body radiation. /2/ Combined penicillin and streptomycin increased survival in dog. /3/ Cross circulation.

/4/ Homologous rat spleen implants or intraperitoneal injections into X-irradiated rats is far less effective than similar mouse spleen therapy in irradiated mice.

416. RADIATION BIOLOGY: GLOSSARY

ALPHA PARTICLE (α): Positively charged particle emitted by radioactive atomic nuclei; usually travelling at high speed, and having a mass number 4 and atomic number 2. **ALPHA RAY (α):** Stream of alpha particles. **ANGSTROM (Å):** A unit of length, used chiefly in expressing short wave lengths; it equals 10^{-8} cm. **ATOM:** Smallest particle of an element which is capable of entering into a chemical reaction. **ATOMIC MASS UNIT (amu):** Exactly 1/16 of the mass of a neutral atom of the most abundant isotope of oxygen, ^{16}O . One amu = 1.660×10^{-24} g = 931 mev = 0.999728 awu. **ATOMIC NUMBER (Z):** Number of orbital electrons in a neutral atom, or the electric charge on the nucleus of an atom, or the number of protons in the nucleus of an atom. **ATOMIC WEIGHT:** Relative weight of an atom compared with the weight of 1 atom of oxygen taken at 16. **ATOMIC WEIGHT (chemical scale):** Average weight of the atoms of an element (of isotope distribution found in nature) referred to the weight of exactly 16 for the average weight of the atoms of oxygen of isotope distribution found in fresh lake or rain water. Atomic weights on the chemical scale are expressed as atomic weight units (awu). The value may be computed from atomic weights on the physical scale by: atomic weight ÷ 1.000272. **ATOMIC WEIGHT (physical scale):** Weight of an atom or the average weight of a mixture of atoms of an element referred to the exact value 16 for the principal isotope of oxygen, ^{16}O . Atomic weights on the physical scale are expressed in atomic mass units (amu). They may be computed from atomic weights on the chemical scale by atomic weight × 1.000272. **ATOMIC WEIGHT UNIT (awu):** Exactly 1/16 of the weighted mean of the masses of the neutral atoms of oxygen of isotopic composition found in fresh lake or rain water. 1 awu = 1.660×10^{-24} g = 1.000272 amu. **ATTENUATION:** Term often used to indicate the decrease in number of particles as a function of thickness of the absorbing medium, and this number of particles may or may not be proportional to the dose because specific ionization changes with the velocity of the particles. **BETA PARTICLE (β):** Electron, negative or positive (positron), emitted from the nucleus during radioactive disintegration. (Symbols β, β⁻, β⁺ are reserved for electrons of nuclear origin.) **BETA RAY (β):** Stream of beta particles. **COLLIMATED:** Beam of radiation limited to the required dimensions. **COSMIC RAYS:** Ionizing rays entering the earth's atmosphere from unidentified extra-terrestrial space and resulting in the presence of photons, electrons, neutrons, protons, mesons, etc., by collisions with atoms in the atmosphere and by radioactive decay. Most penetrating of all radiations. **COULOMB:** Practical unit of electrical charge. **CURIE (c):** A unit of radioactivity defined as the quantity of any radioactive nuclide in which the number of disintegrations per second is 3.7×10^{10} . **DECAY, RADIOACTIVE:** The spontaneous transformation with a measurable life-time of a nuclide into one or more different nuclides. The process involves the emission from the nucleus of alpha particles, electrons, positrons, gamma rays, neutrons or the nuclear capture or ejection of orbital electrons. Rate of decay is usually expressed in terms of half-life. **DEUTERIUM (H²):** The hydrogen isotope of mass number 2 (1 proton, 1 neutron, 1 electron). It has an amu of 2.01474 ± 0.00002 . **DEUTERON:** The nucleus of deuterium (1 proton, 1 neutron). It has an amu of 2.01419 ± 0.00002 . **DISINTEGRATION:** Process of spontaneous breakdown of a nucleus of an atom resulting in the emission of a particle and/or a photon. **DOSE:** A quantity of radiation as defined in the definition of the unit "roentgen." **DOSE ABSORBED (any ionizing radiation):** Amount of energy imparted to matter by ionizing particles per unit mass of irradiated material at the place of interest. It shall be expressed in rads (I.C.R.U., 1953). **Absorbed dose rate** is the absorbed dose per unit of time. **DOSE, AIR (free air dose):** A dose of radiation measured in air at the point of interest, or in the absence of patient (or phantom) or other object, thus excluding secondary radiation, apart from that arising from the air or associated with the source. **DOSE, PERMISSIBLE:** Dose of ionizing radiation (within a specified period) that, in the light of present knowledge, is not expected to cause appreciable bodily injury to a person at any time during his lifetime. **DOSE, PERMISSIBLE WEEKLY:** Dose of ionizing radiation accumulated in one week of such magnitude that, in the light of present knowledge, exposure at this weekly rate for an indefinite period of time is not expected to cause appreciable bodily injury to a person at any time during his lifetime. (For long-continued X- or gamma ray exposure of the whole body it is 0.3 r/wk measured in air.) **DOSE RATE:** Radiation dose received per unit of time.

416. RADIATION BIOLOGY: GLOSSARY (Concluded)

DYNE: Unit of force capable of producing an acceleration of 1 cm/sec/sec to 1 g. **ELECTROMAGNETIC UNIT (emu):** Relates magnetic field to electric current. 3×10^{10} esu of charge = 10 coulombs (the practical unit of charge) = 1 emu. **ELECTRON (e^- or β^-):** Subatomic particle having a rest mass of $(9.1086 \pm 0.0003) \times 10^{-28}$ g, or $1/1836$ mass of a proton, and a charge of negative electricity of $(4.80294 \pm 0.00008) \times 10^{-10}$ esu. (Synonym is "negatron.") **ELECTRON CAPTURE (EC):** Radioactive transformation occurring when a bound electron merges with the nucleus, converting a proton to a neutron, with liberation of energy in the form of a monoenergetic neutrino plus a photon of X-ray characteristic of the new substance. It is a type of beta decay. Electron capture, identified with a literal prefix (e.g., K-electron capture), refers to capture of electrons initially in the designated atomic shell. **ELECTRON VOLT (ev):** Unit of energy. The change in kinetic energy of an electron when it is accelerated through a potential difference of 1 volt. One ev is equivalent to 1.602×10^{12} erg. **100 ELECTRON VOLT YIELD (100 ev yield):** Yield of molecules converted or produced per 100 ev of radiant energy input. **ELECTROSTATIC UNIT OF CHARGE (esu):** The amount of electrical charge which, in a vacuum, will repel a like charge with a force of 1 dyne at a distance of 1 cm. **FISSION, NUCLEAR:** The splitting of a nucleus into more-or-less equal fragments. Fission may occur spontaneously or may be induced by capture of bombarding particles. In addition to the fission fragments, neutrons and gamma rays are usually produced during fission. **GAMMA RAY (γ):** Electromagnetic radiation of short wave length and correspondingly high frequency, emitted by the nucleus of an atom in the course of radioactive decay. (There is no distinction between X-ray photons and gamma ray photons of the same energy.) **HALF-LIFE, RADIOACTIVE:** Time taken for the amount of a radioactive nuclide to decay to half its initial value. **HALF-VALUE LAYER (HVL):** The thickness of a specified absorbing material which, when introduced into the path of an X-ray beam, reduces the dose rate to 1/2 its original value. Also, half-value layer is applied to that layer which reduces the number of radioactive particles, and in many cases the absorbed dose rate, to the half-value. **ISOTOPE:** One of several nuclides having the same number of protons in their nuclei, hence belonging to the same element and having the same atomic number Z, but differing in the number of neutrons and therefore in mass number A. **KILO-ELECTRON-VOLT (keV):** 1000 electron volts. **KILO-ROENTGEN (kr):** 1000 roentgens. **KILOVOLT (kv):** A unit of electrical potential equal to 1000 volts. **KILOVOLT PEAK (kvp):** The crest value of the potential wave in kilovolts. **MASS:** Quantity of matter. **MASS OR NUCLEON NUMBER (A):** Total number of nucleons (protons and neutrons) in the nucleus of an atom or nuclide. **MEGA- or MILLION ELECTRON VOLT (MeV):** 1,000,000 electron volts (unit of energy equal to 1.6×10^{-6} ergs). **MESON:** An elementary particle having a rest mass intermediate between the mass of an electron and that of a proton. All of the known mesons are unstable and short-lived. The meson is a quantum of the nuclear field. **MICROCURIE (μ c):** $1/1,000,000$ of a curie (3.7×10^4 disintegrations per second). **MICROROENTGEN (μ r):** $1/1,000,000$ of a roentgen. **MILLIAMPERE (ma):** $1/1000$ of an ampere. **MILLICURIE (mc):** $1/1000$ of a curie (3.7×10^7 disintegrations per second). **MILLIRAD (mrad):** $1/1000$ of a rad. **MILLIROENTGEN (mr):** $1/1000$ of a roentgen. **MILLIROENTGEN EQUIVALENT PHYSICAL (mrep):** Amount of energy absorption in soft tissue corresponding to 0.093 ergs per gram. **MOLECULE:** Ultimate unit quantity of a compound which can exist by itself and retain all the properties of the original substance. **NEGATRON (β^- , or e^-):** A negative electron (a term sometimes used when necessary to distinguish between positive and negative electrons). **NEUTRINO:** A theoretical particle of very small rest mass very nearly equal to zero, emitted in beta decay and other nuclear reactions. **NEUTRON (n):** A nuclear particle of zero charge and mass number 1; the mass is 1.008984 ± 0.000002 amu. (Neutrons are a constituent of all nuclei except H^1 .) The neutron has a mass slightly greater than that of the proton. **NEUTRON, FAST:** A neutron possessing high kinetic energy. **NEUTRON, SLOW:** A neutron slowed in passage through a scattering material. **NEUTRON, THERMAL:** Neutron with kinetic energy distribution comparable with the kinetic energy distribution caused by thermal agitation of the nuclei composing the medium. **NUCLEON:** A constituent particle of the atomic nucleus (proton, neutron). **NUCLIDE:** A species of atom having a specific mass number (A), atomic number (Z), and atomic mass. **PHOTON:** Corpuscular (quantum) manifestation of electromagnetic radiation. **POSITRON (β^+ , or e^+):** A subatomic particle having a rest mass of $(9.1086 \pm 0.0003) \times 10^{-28}$ g, and a charge of positive electricity of $(4.80294 \pm 0.00008) \times 10^{-10}$ esu; a positive electron. **PROTECTIVE BARRIER:** Barrier of radiation-absorbing material, such as lead, concrete, etc., used to reduce radiation hazards. **PROTECTIVE BARRIER, PRIMARY:** Barrier sufficient to reduce the useful beam to the maximum permissible weekly dose. **PROTIUM (H^1):** Hydrogen isotope of mass 1. **PROTON:** An elementary nuclear particle of mass 1 having a charge equal and opposite to that of an electron. The rest mass is $(1.67245 \pm 0.00005) \times 10^{-24}$ g, or 1.0076 amu. (The nucleus of H^1 is a proton; the proton is one of the constituents of every nucleus.) **PULSATING POTENTIAL (or VOLTAGE):** A potential (or voltage) which undergoes large periodic variations in magnitude at a frequency related to that of the main supply. **QUANTUM:** The smallest quantity of energy constituting a photon of electromagnetic radiation which can be associated with a given phenomenon. (Electromagnetic radiation sometimes appears to consist of waves and at other times of particles.) **QUANTUM ENERGY:** Energy contained in a quantum of radiation and proportional to the frequency of the radiation waves. **RAD (rad):** Unit of absorbed dose; it is the energy absorption of 100 ergs/g of any medium. **RADIATION:** Emission and propagation of energy through space or through a material medium as (a) electromagnetic or elastic waves (X-, gamma, infrared, visible, and ultraviolet rays), and (b) by extension, corpuscular emissions such as alpha, beta, neutron and proton radiation, and mixed or unknown rays such as cosmic rays. **RADIATION, BACKGROUND:** Undesired radiation arising from radioactive material other than that directly under consideration, i.e., cosmic rays, natural radioactivity, insulator leakage, power-line fluctuations, etc. **RADIATION HEAVY PARTICLE:** Particulate ionizing radiation consisting of atomic nuclei of any mass travelling at high speed. Alpha particles or rays constitute a special kind of heavy particle radiation. **RADIATION, IONIZING:** Electromagnetic ionizing radiation (X- or gamma ray photons or quanta), or corpuscular radiation (alpha particles, beta particles, electrons, positrons, protons, neutrons and heavy particles) capable of producing ions directly or by secondary processes. **RADIATION, LEAKAGE:** In the case of X-rays all radiation, except the useful beam, coming from within the X-ray tube and tube housing. **RADIATION, PRIMARY:** Radiation coming directly from the source, i.e., target of the X-ray tube ("useful beam" and leakage radiation), or radioactive material (beta and gamma rays). **RADIATION, SCATTERED:** Radiation which, during passage through a substance, has been deviated in direction, and may also have been modified by increase in wave length (Compton effect) and have had its energy diminished. It is one form of secondary radiation. **RADIATION, SECONDARY:** Radiation, other than primary radiation, emitted by any matter irradiated with X-rays, gamma rays, electrons, neutrons, etc.; it may consist of X-rays, gamma rays, electrons, protons, neutrons, etc., or ultraviolet or visible radiation. **RADIATION, STRAY:** Radiation not serving any useful purpose. It includes leakage radiation, and secondary radiation from irradiated objects, and represents the portion of the radiation against which special protective measures have to be taken. **RADIATION, USEFUL BEAM:** That part of the primary and secondary radiation which passes through the aperture, cone, or other device for collimating the X-ray beam. **RADIATION HAZARD:** The danger to health arising from exposure to ionizing radiation. It may be caused by external radiation or by radiation from radioactive materials within the body. **RADIOACTIVITY:** Spontaneous disintegration of an unstable nuclide with the emission of a particle or a photon to form a different nuclide. **RADIOISOTOPE:** Any radioactive isotope of an element. (Also loosely used as a synonym for radionuclide.) **RELATIVE BIOLOGICAL EFFECTIVENESS (RBE):** The appropriate value of the biological effectiveness of the radiation in question relative to that of X-radiation with an average specific ionization of 100 ion pairs per micron of water, for the particular biological system and biological effect under consideration and for the condition under which the radiation is received. The RBE is expressed in terms of the pertinent biological effectiveness of ordinary X-rays taken as 1. **ROENTGEN (r):** The quantity of X- or gamma radiation such that the associated corpuscular emission per 0.001293 g of air produces, in air, ions carrying one electrostatic unit of electricity of either sign. **ROENTGEN EQUIVALENT MAN (OR MAMMAL) (rem):** The absorbed dose of any ionizing radiation which has the same biological effectiveness as one rad of X-radiation with average specific ionization of 100 ion pairs per micron of water, in terms of its air equivalent, in the same region. A dose in rem is equal to the dose in rads multiplied by the RBE. **ROENTGEN EQUIVALENT PHYSICAL (rep):** The dose of ionizing radiation which produces energy absorption of 93 ergs per gram of soft tissue (rep is being superseded by rad). **ROENTGEN RAYS:** X-rays, usually produced by bombarding a metallic target with high-speed electrons in a suitable device. **TELETERAPY:** Therapeutic irradiation with collimated gamma rays. **TRITIUM (H^3 , or T):** The hydrogen isotope of mass number 3 (1 proton, 2 neutrons, 1 electron). It has an amu of 3.01695, and half-life of 12.5 yr. **VOLT (v):** Practical unit of electric potential, i.e., that potential difference against which 1 joule of work is done in the transfer of 1 coulomb. One volt is equivalent to 10^8 electromagnetic units of potential. **X-RAY:** Electromagnetic ionizing radiation which originates outside the nucleus of the atom, and results from loss of energy of charged particles, e.g., electrons. It is of shorter wave length (less than about 100 Å) than ultraviolet radiation.

417. ALIMENTARY TRACT MICROORGANISMS

Part I: NORMALLY OCCURRING: MAN

Organism	Habitat ¹					Organism	Habitat ¹				
	Mouth	Ileum	Cecum	Appendix	Colon		Mouth	Ileum	Cecum	Appendix	Colon
Bacteria						Bacteria (concluded)					
1 <i>Aerobacter aerogenes</i>		+	+	+	+	26 <i>Proteus mirabilis</i>		+	+	+	+
2 <i>A. cloacae</i>		+	+	+	+	27 <i>P. morganii</i>		+	+	+	+
3 <i>Alcaligenes faecalis</i>		+	+	+	+	28 <i>P. rettgeri</i>		+	+	+	+
4 <i>Bacteroides</i> spp		+	+	+	+	29 <i>P. vulgaris</i>		+	+	+	+
5 <i>Clostridium alcaligenes</i>		+	+	+	+	30 <i>Streptococcus anaerobius</i>	+	+	+	+	+
6 <i>C. angulosum</i>		+	+	+	+	31 <i>S. durans</i>		+	+	+	+
7 <i>C. bifermentans</i>		+	+	+	+	32 <i>S. faecalis</i>		+	+	+	+
8 <i>C. filamentosum</i>		+	+	+	+	33 <i>S. foetidus</i>	+	+	+	+	+
9 <i>C. perfringens</i>		+	+	+	+	34 <i>S. liquefaciens</i>		+	+	+	+
10 <i>C. tertium</i>		+	+	+	+	35 <i>S. mitis</i>	+				
11 <i>C. tetani</i>		+	+	+	+	36 <i>S. pyogenes</i>	+				
12 <i>Dialister granuliformans</i>	+					37 <i>S. salivarius</i>		+	+	+	+
13 <i>D. pneumosintes</i>	+					38 <i>S. zymogenes</i>					
14 <i>Diplococcus pneumoniae</i>	+					39 <i>Veillonella gazogenes</i>	+				
15 <i>Escherichia coli</i>		+	+	+	+	40 <i>V. parvula</i>	+				
16 <i>E. freundii</i>		+	+	+	+	Fungi					
17 <i>Fusobacterium plautivinceni</i>	+					41 <i>Candida albicans</i>	+	+	+	+	+
18 <i>Gaffkyia anaerobia</i>		+	+	+	+	42 <i>C. krusei</i>		+	+	+	+
19 <i>G. tetragena</i>	+	+	+	+	+	43 <i>C. tropicalis</i>		+	+	+	+
20 <i>Klebsiella pneumoniae</i>	+	+	+	+	+	44 <i>Cryptococcus</i> spp		+	+	+	+
21 <i>Lactobacillus</i> spp	+	+	+	+	+	45 <i>Debaryomyces hansenii</i>	+				
22 <i>Micrococcus pyogenes</i> var. <i>albus</i>	+	+	+	+	+	46 <i>Geotrichum brasiliensis</i>		+	+	+	+
23 <i>M. pyogenes</i> var. <i>aureus</i>	+	+	+	+	+	47 <i>Mycoderma pulmonum</i>		+	+	+	+
24 <i>Neisseria catarrhalis</i>	+					48 <i>Saccharomyces</i> spp		+	+	+	+
25 <i>N. sicca</i>	+					49 <i>S. tumefaciens albus</i>	+				

/1/ Bacteria and fungi are not normally present in the stomach, duodenum and jejunum.

Part II: FECAL CONTENT: MAN

Values are on a dry weight of feces basis, unless otherwise indicated; those in parentheses are ranges. Superscripts after numerical values are exponents, not footnotes.

Species or Group of Organisms	Organisms		Species or Group of Organisms	Organisms	
	Units	Value		Units	Value
1 Bacterial content, total (living and dead)	grams per day	8.3	15 Gram-pos. rods with spores	% of all	0.4(0-0.8)
2	% of feces	28(20-35)	16 Free spores	bacteria	2(0-14)
3	No. /g feces ¹	(10-80x10 ¹⁰)	17 Microbial flora, living ²		
4	Total no.	30x10 ¹²	18 <i>Escherichia coli</i> ³	No. /g feces	(10 ⁴ -10 ⁹)
5 Living bacteria: aerobic agar	No. /g feces	(14x10 ⁵ -15x10 ⁸)	19	% of gram-neg.	65
6 Living bacteria: anaerobic agar	No. /g feces	(30x10 ⁵ -12x10 ⁸)	20	% of subjects ⁴	93
7 Gram-neg. bacteria, total	% of all bact.	81(63-97)	21 <i>Aerobacter aerogenes</i>	% of gram-neg.	0.2
8 Gram-neg. rods		71(55-91)	22 Intermediates (gram-neg.)	% of subjects	47
9 Gram-neg. cocci	% of all bacteria	8(1-37)	23 Bacilli, anaerobic ⁵	% of gram-neg.	34.8
10 Gram-neg. spirilla		0.1(0-0.2)	24 Lactobacilli ⁶	No. /g feces ¹	(10 ⁶ -10 ¹²)
11 Gram-neg. spirochetes		1.1(0-11)	25	No. /g feces	(10 ⁶ -10 ¹⁰)
12 Gram-pos. bacteria, total	% of all bact.	17(1-34)	26 Monilia	% of subjects ⁴	Few in 33%
13 Gram-pos. cocci	% of all bacteria	11(0.4-32)	27 Other fungi	% of subjects ⁴	Few in 3-29%
14 Gram-pos. rods		6(1-13)	28 Streptococci (<i>S. faecalis</i>)	No. /g feces	(10 ² -10 ⁷)

/1/ Wet. /2/ In addition to organisms listed, *Clostridia* (mainly *C. perfringens* and *C. lentoputrescens*), *Micrococci*, *Proteus* and *Pseudomonas* spp. and various *Bacterioides* are frequently found in feces. /3/ Various sero- and bio-types, transient and resident. /4/ Present in feces in this percentage of adults. /5/ Non-sporulating. /6/ Non-sporulating, including *Lactobacilli* and *Bacteroides*.

Part III: ALIMENTARY TRACT: MAMMALS AND BIRDS

Values in parentheses are ranges. Superscripts after numerical values are exponents, not footnotes. Values are on wet weight basis.

Animal	Source of Organisms	Species or Group of Organisms	Organisms per g wet wt	Animal	Source of Organisms	Species or Group of Organisms	Organisms per g wet wt
1 Calf ¹	Feces	Aerobes	(2-940x10 ⁷)	28 White rat	Pooled feces	Aerobic flora, total	(20-95x10 ⁸)
2		Anaerobes	(150-950x10 ⁷)	29		Anaerobic flora, total	(45-200x10 ⁸)
3		Coliforms	(2-280x10 ⁷)	30		Coliform bacteria	(25x10 ³ -95x10 ⁶)
4		Enterococci	(10-700x10 ³)	31		Lactobacilli	(6-34x10 ⁸)
5				32		Spore-formers, anaerobic	(2-85x10 ⁴)
6	Stomach	Anaerobic sporing rods	10 ³	33		Coliform bacteria	(10 ³ -10 ⁷)
7		<i>L. acidophilus</i> var. <i>caviae</i>	(10 ⁵ -10 ⁶)	34	Duodenum	Enterococci	(10 ² -10 ⁸)
8		Yeast-like organisms	(10 ³ -10 ⁴)	35		Lactic acid bacteria	(10 ⁵ -10 ⁹)
9				36		Coliform bacteria	(10 ⁴ -10 ⁷)
10	Duodenum-jejunum	Anaerobic sporing rods	10 ³	37	Ileum	Enterococci	(10 ⁵ -10 ⁸)
11		<i>L. acidophilus</i> var. <i>caviae</i>	(10 ⁵ -10 ⁶)	38		Lactic acid bacteria	(10 ⁶ -10 ¹⁰)
12		Yeast-like organisms	(10 ⁴ -10 ⁵)	39			
13				40	Cecal pouch	Coliform bacteria	(10 ⁸ -10 ¹¹)
14		Anaerobic sporing rods	10 ³	41		Enterococci	(10 ⁷ -10 ¹⁰)
15	Ileum	Enterococci	10 ³	42		Lactic acid bacteria	(10 ⁹ -10 ¹¹)
16		<i>L. acidophilus</i> var. <i>caviae</i>	(10 ⁶ -10 ⁷)	43			
17		Yeast-like organisms	(10 ⁴ -10 ⁵)	44	Colon	Coliform bacteria	(10 ⁶ -10 ⁹)
18		Anaerobic sporing rods	10 ³	45		Enterococci	(10 ⁶ -10 ⁸)
19		Enterococci	(10 ³ -10 ⁷)	46		Lactic acid bacteria	(10 ⁸ -10 ¹¹)
20		<i>L. acidophilus</i> var. <i>caviae</i>	(10 ⁵ -10 ⁸)	47			
21		Yeast-like organisms	(10 ⁴ -10 ⁵)	48	Turkey	Bacterium spp. other misc.	
22				49		Gram-pos. rods (<i>L. bifidus</i> types)	(0.7-10x10 ⁹)
23	Colon	Anaerobic sporing rods	10 ³	50		Coliform types	(10 ⁶ -10 ⁸)
24		Enterococci	(10 ³ -10 ⁷)	51		<i>Corynebacterium</i> spp	(0.2-10x10 ⁹)
25		<i>L. acidophilus</i> var. <i>caviae</i>	(10 ⁵ -10 ⁸)			Enterococci	(10 ⁴ -30x10 ⁹)
26		Yeast-like organisms	(10 ³ -10 ⁵)			Lactobacilli, facultative anaerobic (<i>L. acidophilus</i> types)	(2x10 ⁵ -10 ⁸)
27	Rectum	Anaerobic sporing rods	10 ³			<i>Micrococci</i> (<i>Pedioxoccus</i> types) ³	(10 ⁶ -30x10 ⁹)
		Enterococci	(10 ³ -10 ⁵)			Streptococci, anaerobic	(10 ⁶ -10 ⁸)
		<i>L. acidophilus</i> var. <i>caviae</i>	(10 ⁵ -10 ⁸)				
		Yeast-like organisms	(10 ⁴ -10 ⁵)				

/1/ Values are per gram dry weight of samples from calves 1-12 weeks old. /2/ Results with 4 different diets or under starvation conditions.

/3/ Aerobic and facultative anaerobic.

418. RUMEN BACTERIA: GENERAL CHARACTERISTICS

Organisms listed are only those which have been given scientific names, plus unnamed organisms appearing frequently in current literature. They account for only a few of the numerous bacteria that can be isolated from rumen fluid, and do not include many of the important fiber digesters.

	Organism	No. per ml of Rumen Contents	Morphology	Oxygen Relations	Principal End Products of Fermentation	Possible Role in the Rumen
1	<i>Bacteroides succinogenes</i>	$4 \times 10^7 - 4 \times 10^8$	Gram-neg., non-motile, slightly curved, small rods with pointed ends on cellulose agar. ¹	Anaerobic.	Acetic and succinic acids, and uptake of CO ₂ from cellulose.	Vigorous cellulose digesters.
2	<i>Borrelia</i> sp	to 10^8	Gram-neg., small, slender, irregularly coiled spirochete with pointed end. Not double contoured.	Anaerobic.	Acetic and succinic acids, with smaller amounts of CO ₂ , ethanol, formic and lactic acids from glucose.	Fermenter of readily available carbohydrates such as hydrolytic products of starch and cellulose.
3	<i>Butyrivibrio fibrisolvens</i> ²	to 5×10^8	Gram-neg., curved, anaerobic rods with monotrichous flagella.	Anaerobic.	CO ₂ , H ₂ , and butyric, lactic and formic acids from glucose. Acetic acid produced or used.	Fermenter of fiber and readily available carbohydrates.
4	"Cellulolytic cocci" ³	$10^8 - 4 \times 10^8$	Gram-pos. to gram-neg., iodophilic cocci; diplococci to long chains.	Anaerobic.	CO ₂ , H ₂ , ethanol, lactic, acetic, formic, succinic acids from cellulose (Huntgate). Acetic, formic and succinic acids (Sijpesteijh).	Vigorous digesters of cellulose and xylan.
5	<i>Escherichia coli</i> ⁴	to 10^6	Small, gram-neg. rods.	Facultative anaerobe.	Lactic, acetic, formic, succinic acids, ethanol, CO ₂ and H ₂ from glucose.	Possibly none.
6	<i>Lachnospira multiparus</i>	to 10^8	Weakly gram-pos., curved rods with monotrichous flagella.	Anaerobic.	CO ₂ , H ₂ , ethanol and acetic, formic and lactic acids.	Fermenter of readily available carbohydrates.
7	Anaerobic lactobacilli ⁵	to 10^9	Gram-pos. rods of various sizes and shapes, including branched rods.	Anaerobic; some revert to facultative anaerobes.	Lactic acid from glucose.	Fermenters of readily available carbohydrates.
8	<i>Lactobacillus brevis</i> ⁶	to 3×10^6	Gram-pos. rods with rounded ends; short in length to long filaments.	Facultative anaerobe.	Lactic acid from glucose.	Fermenter of readily available carbohydrates.
9	LC ⁷	to 10^9	Gram-variable large diplococci.	Anaerobic.	CO ₂ , H ₂ , acetic, butyric, caproic, and small amount of propionic and valeric acids from glucose.	Fermenter of lactate, readily available carbohydrates and amino acids.
10	<i>Propionibacterium acnes</i> ⁸	$2 \times 10^5 - 7 \times 10^9$	Gram-pos., short rods, metachromatic granules, some branching and longer under acid conditions.	Prefer anaerobic conditions.	Acetic and propionic acids and CO ₂ from glucose or lactate.	Fermenter of lactate and readily available carbohydrates; also proteolysis.
11	<i>Sarcina bakeri</i>	to 1.4×10^6	Large, gram-neg. cocci in pairs, tetroads and larger groups.	Facultative anaerobe.		
12	<i>Selenomonas ruminantium</i> ⁹	to 10^8	Gram-neg., large, crescentic rods; tuft of flagella usually attached to concave side of cell.	Anaerobic.	Propionic, acetic and lactic acids from glucose. Propionic and acetic acids from lactate.	Fermenter of readily available carbohydrates. Some strains ferment lactate.
13	<i>Streptococcus bovis</i> ¹⁰	$10^5 - 6 \times 10^9$	Gram-pos. cocci in pairs; occasionally short chains.	Facultative anaerobe.	Lactic acid from glucose.	Active starch hydrolyzer; fermenter of readily available carbohydrates.
14	<i>Succinivibrio dextrinosolvens</i> ¹¹	to 10^9	Gram-neg., curved rods with monotrichous flagella.	Anaerobic.	Succinic and acetic acids from glucose.	Fermenter of the hydrolytic products of starch and other readily available carbohydrates.
15	<i>Veillonella gasogenes</i>	to 10^5	Gram-neg. to gram-variable masses of cocci.	Anaerobic.	Acetic and propionic acids, CO ₂ and H ₂ from lactate.	Fermenter of lactate and other organic acids and purines.

/1/ In sugar media, organisms may be larger, swollen, and exhibit bipolar staining. /2/ Similar to RO-H types of Huhtanen and Gall. /3/ A heterogeneous group requiring more study before species are designated. /4/ In large numbers only in sheep and very young calves. /5/ Predominantly in young calves and mature ruminants on rations with large amounts of readily available carbohydrates. /6/ These organisms have been isolated only from calves. /7/ Similar to RO-C8 of Huhtanen and Gall. /8/ Similar to RO-C1 of Huhtanen and Gall. /9/ Includes RO-HD types of Huhtanen and Gall. /10/ In large numbers only in animals receiving large amounts of readily available carbohydrates. /11/ Present in large numbers only in animals fed high grain ration.

419. ARTHROPODS IN RELATION TO DISEASE: MAN

Part I: DISEASE VECTORS

Unless otherwise indicated in the right-hand column ("Relationship"), infection or infestation is transmitted to man when bitten by the arthropod vector or host.

Vector	Etiologic Agent	Disease or Infestation	Arthropod-Pathogen-Infection Relationship
Crustacea (Crabs, Lobsters)			
1 Crabs and crayfish, fresh-water	<i>Paragonimus westermani</i> .	Paragonimiasis (pulmonary distomiasis, endemic hemoptysis).	Second intermediate host (snail first intermediate host); no multiplication of pathogen; man infested by ingestion of inadequately cooked host.
2 Flea, water (Cyclops spp)	<i>Diphyllbothrium</i> (sub-genus <i>Spirometra</i>).	Sparganosis.	First intermediate host; no multiplication of pathogen; man infested by swallowing host Cyclops.
3 Flea, water (Cyclops, <i>Diaptomus</i> spp)	<i>D. latum</i> .	Diphyllbothriasis (fish tapeworm).	First intermediate host; no multiplication of pathogen; man infested by swallowing infested fish.
4 Flea, water (Cyclops spp).	<i>Dracunculus medinensis</i> .	Dracontiasis (Medina worm).	First intermediate host; no multiplication of pathogen; man infested by swallowing host Cyclops.
Diplopoda (Millipedes)			
5 <i>Fontaria virginensis</i>	<i>Hymenolepis diminuta</i> ¹ .	Rat tapeworm.	Pathogen develops from embryo to larva in arthropod hemocoel; definitive host infested by swallowing adult arthropod host.
6 <i>Julus</i> sp			
Arachnida (Mites and Ticks)			
7 Mite, mouse (<i>Allodermanysus sanguineus</i>)	<i>Rickettsia akari</i> .	Rickettsial pox.	Pathogen multiplies in mite; congenital transmission not demonstrated.
8 Mite, oribatid (<i>Oribatidae</i>)	<i>Bertiella studeri</i> , <i>Inermicapsifer arvicandialis</i> .	Anoplocephaline tapeworm.	Pathogen matures from embryo to larva, without multiplication, in mite hemocoel. Man infested by swallowing host.
9 Mite, rat (<i>Bdellonyssus bacoti</i>)	<i>Rickettsia typhi</i> .	Murine typhus fever (experimental).	Pathogen multiplies in mite gut; experimental animal infected by mite bite. ²
10 Mite, red chigger (<i>Trombicula</i> spp)	<i>Rickettsia tsutsugamushi</i> .	Scrub typhus (Japanese river fever).	Congenitally transmitted in mite.
11 Tick (<i>Amblyomma</i> spp, <i>Dermacentor</i> spp, <i>Haemaphysalis</i> spp, <i>Hyalomma</i> sp, <i>Ornithodoros</i> spp, <i>Rhipicephalus</i> spp)	<i>Rickettsia australis</i> , <i>R. conori</i> , <i>R. rickettsi</i> .	Spotted fever.	Pathogen multiplies in wall of tick midgut; congenitally transmitted in tick.
12 Tick (<i>Amblyomma americanum</i> , <i>Dermacentor</i> spp); many other ticks	<i>Pasteurella tularensis</i> .	Tularemia.	Pathogen multiplies in tick gut and hemocoel; congenitally transmitted in some ticks.
13 Tick (<i>Dermacentor andersoni</i> , <i>Haemaphysalis humerosa</i> , <i>Rhipicephalus sanguineus</i>)	<i>Coxiella burnetii</i> .	Q fever ³ , Rocky Mt. spotted fever, tularemia.	Pathogen multiplies in wall of tick midgut.
14 Tick (<i>Ornithodoros</i> spp)	<i>Borrelia</i> spp.	Enzootic-endemic relapsing fever.	Pathogen multiplies in tissues of tick outside gut.
Insecta (True Insects) ⁴			
15 Bug, cone nose (<i>Panstrongylus</i> , <i>Triatoma</i> spp)	<i>Trypanosoma cruzi</i> .	Chagas' disease.	Pathogen multiplies in bug midgut; infection by fresh bug feces in contact with mucous membranes or scarified skin.
16 Flea, cat (<i>Ctenocephalides felis</i>)			
17 Flea, dog (<i>C. canis</i>)	<i>Dipylidium caninum</i> .	Dog tapeworm.	Pathogen develops from embryo to larva in flea hemocoel; swallowing flea causes infestation.
18 Flea, human (<i>Pulex irritans</i>)			
19 Flea, rodent (<i>Xenopsylla cheopis</i> and egg); other rat fleas	<i>Hymenolepis diminuta</i> ¹ .	Rat tapeworm	Pathogen develops from embryo to larva in flea hemocoel; swallowing flea causes infection.
20 Flea (<i>X. cheopis</i> , possibly <i>Pulex irritans</i>)	<i>Pasteurella pestis</i> .	Plague.	Pathogen multiplies in flea gut.
21 Flea (<i>X. cheopis</i>); occasionally other fleas	<i>Rickettsia typhi</i> .	Murine typhus fever.	Pathogen multiplies in flea midgut epithelium; man infected by flea feces or crushed flea rubbed into skin.
22 Fly, horse (<i>Chrysops</i> , <i>Tabanus</i> spp)	<i>Pasteurella tularensis</i> .	Tularemia.	Mechanical transmission from mouth parts of fly to man (usually via food).
23 Fly, house (<i>Musca domestica</i>); and other spp of Muscidae	<i>Salmonella typhosa</i> , <i>S. paratyphi A</i> , other <i>Salmonella</i> and <i>Shigella</i> spp, <i>Vibrio cholerae</i> , other enteric diseases.	Typhoid and paratyphoid fevers, dysenteries, cholera.	Mechanical "filth-borne" transmission by setae, feet, regurgitation and defecation into food or drinking water.
24 Fly, mango (<i>Chrysops</i> spp)	<i>Loa loa</i> .	Loiasis (filariasis).	Pathogen matures from embryo to larva without multiplication in fly tissues.
25	<i>Bartonella bacilliformis</i> .	Bartonellosis (Carrión's disease, Verruga peruana).	Pathogen multiplies in fly midgut.
26 Fly, sand (<i>Phlebotomus</i> spp)	<i>Charon</i> sp.	Sand-fly fever.	Pathogen multiplies in fly tissues.
27	<i>Leishmania donovani</i> , <i>L. tropica</i> , <i>L. brasiliensis</i> .	Visceral and cutaneous leishmaniasis, mucocutaneous leishmaniasis.	Pathogen multiplies in fly midgut.
28 Fly, tsetse (<i>Glossina</i> spp)	<i>Trypanosoma gambiense</i> , <i>T. rhodesiense</i>	African trypanosomiasis.	Pathogen multiplies in midgut and salivary glands of fly.
29 Gnat (<i>Culicoides</i> spp)	<i>Acanthocheilonema perstans</i> , <i>A. streptocerca</i> , <i>Mansonella ozzardi</i> .	<i>Acanthocheilonema</i> tiasis, Ozzard's filariasis.	Pathogen matures from embryo to larva, without multiplication in gnat tissues.
30 Gnat (<i>Simulium</i> spp); black flies, buffalo flies, coffee flies	<i>Onchocerca volvulus</i> .	Onchocerciasis (filariasis).	
31 Gnat, eye (<i>Hippelates pusio</i>)	Various bacteria, etc.	Conjunctivitis, pink eye.	Mechanical transmission.

/1/ *Hymenolepis diminuta* not commonly regarded as pathogenic to man. /2/ Reported experimental transmission not confirmed, nor has rat mite ever been shown to transmit murine typhus to man. /3/ Ticks of negligible or no significance in actual transmission of Q fever in the United States, the usual mode of transmission being via the respiratory route. /4/ The earwig (*Anisolabis annulipes*), dung beetles (many spp), roaches (*Blattella* and *Periplaneta* spp), and moth larvae (a few spp) are not included in the table, as they either transmit pathogens to man so rarely as to be medical curiosities, or they transmit parasites not generally regarded as pathogenic to man. /5/ Human infestation with the dog tapeworm in this manner extremely rare.

419. ARTHROPODS IN RELATION TO DISEASE: MAN (Continued)

Part I: DISEASE VECTORS (Concluded)

Unless otherwise indicated in the right-hand column ("Relationship"), infection or infestation is transmitted to man when bitten by the arthropod vector or host.

Vector	Etiologic Agent	Disease or Infestation	Arthropod-Pathogen-Infection Relationship
		Insecta (True Insects) ⁴ (concluded)	
32 Louse, body (<i>Pediculus humanus</i>)	<i>Rickettsia prowazeki</i> .	Epidemic typhus fever.	Pathogen multiplies in epithelium of louse midgut; man infected by feces, or crushing on skin.
33	<i>Rickettsia quintana</i> .	Trench fever.	Pathogen probably multiplies in lumen of louse midgut; man infected by feces, or crushing on skin.
34	<i>Borrelia recurrentis</i> .	Epidemic relapsing fever.	Pathogen multiplies in tissues of louse outside gut; man infected by crushing on skin.
35 Louse, dog (<i>Trichodectes canis</i>)	<i>Dipylidium caninum</i> .	Dog tapeworm.	Pathogen develops from embryo to larva, without multiplication in louse hemocoel; man possibly infested by swallowing louse. ⁵
36 Mosquito (<i>Aedes</i> spp)	<i>Charon evagatus</i> .	Yellow fever.	
37 Mosquito (<i>Aedes</i> spp, <i>Armigeres obturans</i>)	Dengue virus.	Dengue.	Pathogen multiplies in mosquito tissues.
38 Mosquito (<i>Aedes</i> spp, <i>Culex</i> spp, <i>Mansonia titillans</i>)	<i>Erro</i> spp.	Certain encephalitides.	
39 Mosquito (<i>Anopheles</i> spp)	<i>Plasmodium falciparum</i> , <i>P. malariae</i> , <i>P. ovale</i> , <i>P. vivax</i> .	Malaria fever.	Pathogen completes sexual cycle, then multiplies by sporogony in mosquito.
40 Mosquito (<i>Anopheles</i> spp, <i>Aedes</i> spp, <i>Culex</i> spp)	<i>Wuchereria bancrofti</i> .	Bancroft's filariasis.	Pathogen matures from embryo to larva without multiplication in mosquito tissues.
41 Mosquito (<i>Anopheles</i> spp, <i>Mansonia</i> spp)	<i>Wuchereria malayi</i> .	Malayan filariasis.	

/4/ The earwig (*Anisobas annulipes*), dung beetles (many spp), roaches (*Blattella* and *Periplaneta* spp), and moth larvae (a few spp) are not included in the table, as they either transmit pathogens to man so rarely as to be medical curiosities, or they transmit parasites not generally regarded as pathogenic to man. /5/ Human infestation with the dog tapeworm in this manner extremely rare.

Part II: AGENTS OF DIRECT INJURY

Arthropod	Geographical Distribution	Reservoir or Source	Injury
		Chilopoda (Centipedes)	
1 Centipede (<i>Scolopendra</i> spp)	World-wide.	Hidden under various objects.	Envenomization.
		Arachnida (Mites, Ticks, Scorpions, Spiders)	
2 Mite, follicle (<i>Demodex folliculorum</i>) ¹		Mammals.	Mild pruritis; follicular mange.
3 Mite, cheese (<i>Tyroglyphus</i> spp)		Cheese, grain, cereals, fruits.	Dermatitis.
4 Mite, grain (<i>Glyciphagus</i> spp)			Intestinal acariasis, grocer's itch, tropical eosinophilia, dermatitis.
5 Mite, grain itch (<i>Pyemotes ventricosus</i>)	World-wide.	Grain, seeds, straw.	Dermatitis, pruritis.
6 Mite, harvest, or chigger (<i>Eutrombicula</i> spp)		Weeds, grass, scrub.	Dermatitis, sucking of tissue fluids, allergy to arthropod saliva.
7 Mite, itch (<i>Sarcoptes scabiei</i>)		Man.	Sarcoptic acariasis, scabies.
8 Scorpion (<i>Centruroides</i> , <i>Buthus</i> , <i>Tityus</i> spp)	Tropics.	Under well-protected objects.	Envenomization.
9 Spider, black widow (<i>Latrodectus mactans</i> , other spp)	World-wide.	Protected dark places, latrines.	Arachnidism, envenomization.
10 Tick (<i>Dermacentor</i> , <i>Ornithodoros</i> , <i>Ixodes</i> spp)	N. America, Africa, Europe.	Mammals.	Tick paralysis, poisons in tick saliva. Vector organisms causing Rocky Mt. spotted fever.
		Pentastomida (Tongueworms)	
11 Worm, tongue (<i>Armillifer</i> , <i>Linguatula</i> , <i>Porocephalus</i> spp)	World-wide.	Reptiles, birds, mammals.	Linguatulosis, porocephalosis, endoparasites of mouth, throat, lung.
		Insecta (True Insects) ²	
12 Ant (<i>Solenopsis</i>)		Hives, nests.	Envenomization.
13 Bedbug (<i>Cimex</i> spp)	World-wide.	Dwellings, public conveyances.	Bites, allergic reactions to saliva of bedbug.
14 Botfly (<i>Gasterophilus</i> spp) larva		Horse.	Irritation of skin, mucous membranes, eyes.
15 Botfly, human (<i>Dermatobia hominis</i>), larva	S. America, W. Indies, tropical N. America.	Forests (eggs transported by certain mosquitoes, ticks, assassin bugs).	Burrows into exposed skin, causes painful furuncular skin lesions.
16 Botfly, sheep (<i>Oestrus ovis</i>), larva	World-wide.	Sheep.	Inflammation of eyes, nose, mouth, ears, sinuses; skin lesions.
17 Bug, assassin (<i>Reduvius</i> , <i>Rasahus</i> spp)	N. and S. America.	On plants, lights, house walls, under rocks.	Stinging bites, allergic reactions to saliva of bug.
18 Bug, conenose (<i>Panstrongylus</i> , <i>Triatoma</i> , <i>Rhodnius</i> spp)	World-wide.	Dwellings, dark hiding places, rodent harborages.	Allergic reactions to saliva of bug.
19 Chigoe or jigger, sand flea (<i>Tunga penetrans</i>)	S. America, W. Indies, Africa.	Homes, buildings, dwellings.	Cutaneous invasion, infection.
20 Flea, cat and dog (<i>Ctenocephalides felis</i> , <i>C. canis</i>)		Breeding areas or mammalian hosts.	Severe bites, allergic reactions, extreme annoyance. Vector of organisms causing epidemic typhus.
21 Flea, human (<i>Pulex irritans</i>)			
22 Flea, rat (<i>Xenopsylla</i> spp)			
23 Fly, black (<i>Simulium</i> spp)		Breeding areas.	Bites, allergic reactions.
24 Fly, deer (<i>Chrysops</i> spp), adult	World-wide.	Mammalian hosts.	Severe bites, allergic reactions, extreme annoyance.
25 Fly, heel, or cattle grub (<i>Hypoderma</i> spp), larva		Cattle.	Cutaneous or ocular invasion, furuncular lesions, pain, inflammation.
26 Fly, horse (<i>Tabanus</i> spp), adult		Mammalian hosts.	Severe bites, allergic reactions.
27 Fly, primary screwworm (<i>Callitroga hominivorax</i>), larva	W. Hemisphere (tropical, subtropical areas).	Adults: manure, meat, serous exudates; maggots: clean flesh.	Painful lesions of sinuses, ears, nose, anus, skin.

/1/ Now believed to be of little importance in man. /2/ Includes blister beetles and caterpillars of the genus *Megalopyge* which have stinging hairs.

419. ARTHROPODS IN RELATION TO DISEASE: MAN (Concluded)

Part II: AGENTS OF DIRECT INJURY (Concluded)

Vector	Geographical Distribution	Reservoir or Source	Injury
Insects (True Insects) ² (concluded)			
28 Fly, tumbu (Cordylobia anthropophaga), larva	Africa.	Dog, rat.	Cutaneous invasion, furuncular lesions, myiasis.
29 Fly (Wohlfahrtia spp) ³ , larva	World-wide.	Various mammals.	Larvae penetrate tender areas of unbroken skin causing inflammation, furuncles.
30 Gadfly, Russian (Rhino-estrus purpureus), larva	N. Europe, Asia.	Host organisms.	Inflammation of eyes, nose, mouth, ears, sinuses and skin by tissue penetration.
31 Honey-bee (Apis mellifera), wasp (Vespula spp); other bees		Hives, nests, flowers, tunnels.	Envenomization; allergy.
32 Louse, body (Pediculus humanus)	World-wide.	Man.	Pediculosis, skin irritation.
33 Louse, pubic or "crab" (Phthirus pubis)			
34 Maggot, Congo floor (Auchmeromyia luteola)	Africa.	Shady places, native huts.	Blood loss from bloodsucking larvae.
35 Mosquitoes (several genera)	World-wide.	Water, moist places.	Severe bites, secondary infections, allergic reactions. Vectors of organisms causing dengue, malaria and yellow fever.
36 Punkies (Culicoides spp)			Skin bites, eye irritation.

/2/ Includes blister beetles and caterpillars of the genus Megalopyge which have stinging hairs. /3/ A "flesh fly" of the order Sarcophagidae (Sarcophaga, Wohlfahrtia).

420. SELECTED ARTHROPOD PARASITES: MAMMALS, BIRDS

Many of the arthropods listed are known to be parasites of man. Some of these are identified by an asterisk (*).

Arthropod	Geographic Distribution	Location, Free Stage	Host	Location in Host	Effect on Host
Arachnida (Mites, Ticks)					
1 Chigger (Eutrombicula alfreddugesi)	N. and S. America, West Indies.	Active forms, in grasses, shrubs, brambles.	Domestic and wild vertebrates.	External	Injection and toxins, sometimes death (small poultry); larvae are bloodsuckers.
2 Mite, chicken (Dermanyssus gallinae)	World-wide.	Eggs, non-feeding larvae, nymphs, adults in crevices of coops, roosts.	Poultry, other birds.		Decreased egg production, retarded growth, anemia, sometimes death. Vector of organisms causing spirochetosis, fowl cholera. Larvae, nymphs, adults bloodsuckers; nocturnal feeders only.
3 Mite, dog follicle (Demodex canis)		None.	Dog.		Follicle inflammation; mange; thickened skin, alopecia, emaciation, sometimes death.
4 Mite, ear (Otodectes cyanotis)			Dog, cat, ferret.		Inflammation, ear scabs, head-shaking, scratching, droopy ears with discharge; epileptiform fits (severe cases).
5 Mite, itch (Sarcoptes scabiei)*			Most mammals, sheep (on head).		Scratching, papules, vesicles, keratinization, alopecia, mange, emaciation, sometimes death.
6 Mite, northern fowl (Bdellonyssus sylvarum)	United States, Canada, Mexico, Europe, S. Africa.	Eggs on feathers, in nests; other stages on surroundings.	Poultry, wild birds.	External; on body and feathers.	Skin lesions, egg reduction, retarded growth, anemia. Harbors neurotropic viruses. Larvae, nymphs, adults bloodsuckers.
7 Mite, scab (Psoroptes equi v. ovis)	World-wide.	None.	Sheep (other varieties on various domestic animals).	External; all active stages on skin around edge of lesions.	Scabbing; wool loss from biting, scratching; emaciation, sometimes death.
8 Mite, scaly leg (Knemidokoptes mutans)			Chicken, turkey, other domestic birds.	External; all active stages in tunnels between scales, feet, legs, neck, comb.	Inflammation, keratinization between scales of feet, legs, lameness.
9 Tick, American dog- (Dermacentor variabilis)	N. America.	Eggs on soil; unfed larvae, nymphs, adults on vegetation until host is found.	Primarily dog; other domestic and wild animals.	External; on host only, while feeding. Larvae, nymphs mainly attack rodents and other small animals.	Skin damage. Vector of organisms causing bovine anaplasmosis, tularemia, Rocky Mt. spotted fever. Larvae, nymphs, adults bloodsuckers.
10 Tick, black-legged (Ixodes ricinus scapularis)	Europe, some other countries.	Eggs on soil; larvae, nymphs, adults on grass and shrubbery until host is found.	Primarily dog; other domestic and wild animals.	External; adults on head, neck of dog; on flank, leg, under tail of other animals. On host only while feeding.	Anemia. Vector of cattle red water fever, louping-ill virus, tick-borne fever virus of sheep. Larvae, nymphs blood suckers in ear, eyelid, head, rarely body.
11 Tick, brown dog- (Rhipicephalus sanguineus)*	World-wide.	Active forms near habitat of dog.	Dog mainly; occasionally other animals.	External.	Vector of organisms causing canine piroplasmosis, cattle gall sickness. Larvae, nymphs, adults bloodsuckers.
12 Tick, cattle (Boophilus annulatus)*	N. America.	Eggs on soil; unfed larvae on grass.	Primarily ungulates; other animals.	External.	Damage to hide; reduction of milk output. Vector of organisms causing Texas cattle fever. Larvae, nymphs, adults blood suckers.
13 Tick, ear (Otobius megnini)*	United States, Mexico, S. America, S. Africa.	Eggs on ground, in cracks; adults and unattached larvae in out-buildings.	Domestic animals.	Inside ears.	Ear inflammation, anorexia, dullness, sometimes death. Larvae, nymphs bloodsuckers.

420. SELECTED ARTHROPOD PARASITES: MAMMALS, BIRDS (Continued)

Many of the arthropods listed are known to be parasites of man. Some of these are identified by an asterisk (*).

Arthropod	Geographic Distribution	Location, Free Stage	Host	Location in Host	Effect on Host
Arachnida (Mites, Ticks) (concluded)					
14 Tick, fowl (Argas persicus)	Warm and temperate semi-arid regions of world.	All stages in crevices, cracks of housing and under bark of trees.	Domestic fowl; occasionally wild birds.	External; on host only while feeding; of organisms causing fowl spirochaetosis, spiroplasmosis. Nymphs, adults bloodsuckers.	Anemia, leg weakness, egg reduction, occasionally death. Vector of organisms causing Rocky Mt. spotted fever, Q fever.
15 Tick, lone star (Amblyomma americanum)*	North, Central, and South America.	Eggs in soil; unfed larvae, nymphs, adults on grass.	Cattle, dog, horse, goat, sheep; occasionally birds.	External; on host only while feeding.	Damage to hide; milk reduction. Vector of organisms causing Rocky Mt. spotted fever, Q fever.
16 Tick, Rocky Mountain wood- (Dermacentor andersoni)*	Western N. America.	Eggs on soil.	Most mammals.	External; larvae, nymphs on most small animals; adults usually on larger animals during feeding periods.	Paralysis, particularly in sheep. Vector of organisms causing Rocky Mt. spotted fever, tularemia, equine encephalomyelitis, anaplasmosis. Larvae, nymphs, adults bloodsuckers.
Pentastomida (Tongueworms)					
17 Worm, tongue (Linguatula serrata)	World-wide.	Eggs swallowed, hatched in alimentary tract of herbivores; larvae, nymphs develop in mesenteries.	Mammals, birds, reptiles.	Eggs expelled in respiratory tract; adults in nasal passages.	Severe irritation and blocking of nasal passages.
Insecta (True Insects)					
18 Bedbug (Cimex lectularius)*	World-wide.	All stages in cracks, crevices, similar hiding places.	Domestic animals, poultry.	External.	Nymphs, adults bloodsuckers; irritate skin, cause welts.
19 Blowfly, black (Phormia regina) ¹		Pupae in soil; adults in pastures.	Sheep, other mammals.	Eggs in hair or wool; larvae in wounds; eggs and larvae also in carcasses.	Extension and infection of wounds, marring of wool, emaciation.
20 Botfly, horse (Gasterophilus intestinalis) ²		Pupae in soil; adults attack animals only in daytime.	Ass, horse, mule, rarely other animals.	Eggs on foreleg fetlock hairs, larvae (maggots) in mouth, pharynx, stomach.	Extension and infection of wounds.
21 Botfly, human (Dermatobia hominis)*		S. America, West Indies, tropical N. America.	Eggs glued to other arthropods, and hatch when reach suitable host.	Dog, swine, mule, cattle, wild animals.	Larvae leave transport arthropod on contact with host; penetrate skin.	Boil-like skin lesions; reduced milk production, damage to hide; decreased growth rate.
22 Botfly, sheep (Oestrus ovis)	World-wide.	Pupae on ground; adults in warm corners, crevices.	Sheep, rarely goat.	Larvae in nasal cavities, sinuses.	Mucosal irritation, nasal discharge, emaciation, sometimes death.
23 Bug, cone nose (Triatoma sanguisuga) ³		All stages commonly found in or close to rodent nests or habitats.	All domestic animals, poultry; wood rat normal host.	External	Nymphs and adults bloodsuckers, cause swelling, anemia.
24 Flea, cat (Ctenocephalides felis)*		Immature forms associated with nest or sleeping area of host; adults on ground part of time.	Cat, dog, other animals.		Coat damaged from biting, scratching. C. canis and C. felis vectors of dog- and dwarf tapeworms, heart-worm, plague, epidemic typhus. Adults are bloodsuckers.
25 Flea, dog (C. canis)		Immature forms associated with nest or sleeping area of host.	Dog, swine, other animals.		Anemia, sometimes death. Adults are bloodsuckers.
26 Flea, human (Pulex irritans)*			Poultry, domestic animals, rodents.		
27 Flea, sticktight (Echidnophaga gallinacea)*	World-wide, especially warm climates.	Immature forms associated with nest or sleeping area of host.	External; skin, comb, wattles, around eyes and ears.	Vesicles, red swelling, anemia, toxemia, death. S. occidentalis and S. glossonae are vectors of turkey leucocytozoan disease; some spp are vectors of onchocerciasis of man and cattle. Adults bloodsuckers.	
28 Fly, black (Simulium spp) ⁴	World-wide in temperate to subarctic climates.	Immature forms on under sides of stones in moderate running streams.	All warm-blooded animals.	External; on bare parts of head, body, legs, under wings.	Adults bloodsuckers during day; vector of organisms causing anaplasmosis.
29 Fly, black horse- (Tabanus atratus)	N. America.	Immature forms in leaves and mud in and near streams, ponds.	Most warm-blooded animals.	External.	Vector of tularemia, surra. Adults bloodsuckers.
30 Fly, deer (Chrysops discalis)	Western N. America.	Eggs near water; larvae in water; pupae in mud.	Principally horse, cattle.	External, mainly on underside of abdomen, neck, withers.	Mild to extensive subcutaneous pustular lesions; occasionally death.
31 Fly, flesh (Wohlfahrtia vigil)*	N. America.	Pupae on ground; larvae in woods.	Rabbit, mink, guinea pig, young of domestic and wild animals.	Larvae in wounds.	Invasion of wounds, suppuration.
32 Fly, greenbottle (Phaenicia sericata)	World-wide, except S. America and Pacific Islands.	Adults free-living; deposit eggs on flesh, soiled wool; pupae in soil.	Sheep, goat, other animals.	Larvae on skin, in wounds.	Weight loss; milk reduction. Adults bloodsuckers.
33 Fly, horn (Siphona irritans)	Europe, America.	Eggs, maggots in fresh dung; pupae in dung or soil.	Cattle, other animals.	External.	Adults cause decreased productivity of livestock. Vector of several tapeworm species, mechanical vector of many bacterial and protozoan pathogens and helminth eggs.
34 Fly, house (Musca domestica)	World-wide.	Immature forms in manure and decayed matter; adults in buildings.	Any larger animal with lesions or secretions.	External; adults ingested by host.	

/1/ The blowfly (*Chrysomya chloropyga*) of Africa is similar to the black blowfly in its parasitism of sheep. /2/ The nose botfly (*Gasterophilus haemorrhoidalis*) and throat botfly (*G. nasalis*) are similar in many respects to the horse botfly. /3/ Sixteen spp of *Triatoma* found in Western Hemisphere, some of which are as important and as widely distributed as *T. sanguisuga*. /4/ Other *Simulium* spp that are important blackfly pests of livestock are *S. articum*, *S. occidentalis*, *S. ornatum*, *S. vittatum*.

420. SELECTED ARTHROPOD PARASITES: MAMMALS, BIRDS (Concluded)
Many of the arthropods listed are known to be parasites of man. Some of these are identified by an asterisk (*).

Arthropod	Geographic Distribution	Location, Free Stage	Host	Location in Host	Effect on Host
Insecta (True Insects) (concluded)					
35 Fly, louse or tick; ked (<i>Hippobosca equina</i> , <i>Melophagus ovinus</i>)	Most parts of world.	Larvae retained in female until mature; pupae on wool and feathers.	Horse, cattle, dog, sheep and birds, occasionally goat.	External; pupae attached to wool or feathers.	Anemia; wool stained, damaged from rubbing. Adults bloodsuckers. <i>H. equina</i> is mechanical vector of anthrax.
36 Fly, primary screw-worm (<i>Callitroga hominivorax</i>)* ⁵	W. Hemisphere (tropical, subtropical areas).	Pupae in soil; adults in pastures.	Obligatory parasite of warm-blooded animals including livestock, wild mammals, dog, cat.	Eggs deposited on edges of wounds.	Infect, extend wounds, prevent healing, invariably kill untreated host.
37 Fly, sand (<i>Phlebotomus papatasi</i>)*	Mediterranean region, southern Europe, Asia.	Immature forms in dark moist places, manure.	Warm-blooded animals.	External.	Swelling at site of bite; vector of organisms causing papataci fever. Adults nocturnal bloodsuckers.
38 Fly, stable (<i>Stomoxys calcitrans</i>)*	World-wide.	Immature forms in manure and other moist organic waste.	Most mammals and birds.		Weight loss; milk reduction. Vector of poultry tapeworms, filariae, spiruroids; mechanical vector of surra. Adults bloodsuckers.
39 Fly, tsetse (<i>Glossina morsitans</i>)*	Central Africa.	Larvae pass from female when ready to pupate in soil.	Cattle, other animals.		Vector of organisms causing cattle and horse nagana, sleeping sickness to man. Adults bloodsuckers.
40 Grub, common cattle- (<i>Hypoderma lineatum</i>)	Prevalent in America, Europe, India, N. Asia.	Pupae in soil; adults in pastures.	Cattle, rarely horse.	Eggs on hair of legs, body; larger larvae form tumor under skin of back.	Skin perforation, hide and flesh damage, milk reduction.
41 Grub, northern cattle- (<i>H. bovis</i>)	N. America.	None.	Cattle.	External; eggs Reduced vigor, weight gains; hairs; nymphs, irritation, scaly skin. adults feed on skin.	
42 Louse, cattle biting (<i>Bovicola bovis</i>)			All domestic fowl.	External; nymphs Scabbing of skin, wasting; loss in adults on skin. egg production around vent; eggs attached to feathers.	
43 Louse, chicken body- (<i>Menacanthus stramineus</i>)	World-wide.		Chicken, partridge.	External; nymphs Unthriftness. adults on skin and feathers of head, neck; eggs on feathers.	
44 Louse, chicken head- (<i>Cuculotogaster heterographus</i>)			Dog.	External; eggs Scaly skin from rubbing, scratching. on hair; nymphs and adults feed on skin.	
45 Louse, dog biting (<i>Trichodectes canis</i>)	N. America.		Swine.	External; eggs Dermatitis, skin sores, retarded growth. Nymphs, adults bloodsuckers. Vector of organisms causing swine pox.	
46 Louse, hog (<i>Haematopinus suis</i>)			Chicken, duck, pigeon, turkey.	External; eggs, nymphs, adults Scaling and scabbing. feed on scales.	
47 Louse, shaft (<i>Menopon gallinae</i>)	World-wide.		Cattle.	External; eggs on shaft or at base of hairs. Hair damage from rubbing; stunting; reduction of milk output. Nymphs, adults bloodsuckers.	
48 Louse, short-nosed cattle- (<i>Haematopinus eurysternus</i>) ⁶			External.	Adult females bloodsuckers. Vector of organisms causing equine encephalomyelitis.	
49 Mosquito (<i>Aedes dorsalis</i>)*	N. America, Europe, northern Africa.	Immature forms in moist soil; eggs survive long periods of drying in soil.	Warm-blooded animals.	External, where hair or feathers are thinnest.	A. punctipennis is vector of organisms causing dog heartworm. C. quinquefasciatus is vector of organisms causing avian malaria, fowl pox. Adult females bloodsuckers.
50 Mosquito (<i>Anopheles punctipennis</i>)*	N. America.	Immature forms in streams, ponds of hilly country.	Warm-blooded animals, especially birds.		
51 Mosquito, southern house- (<i>Culex quinquefasciatus</i>)*	World-wide from 60°N to 50°S latitudes.	Immature forms in stagnant water, ponds and ditches.			

/5/ Adult stage of the secondary screwworm fly (*C. macellaria*) resembles the primary screwworm fly in appearance, but differs from the latter in being a secondary invader (facultative parasite), and breeding in carcasses; the larvae occasionally infest wool or necrotic wounds. /6/ Also applies to the long-nosed cattle louse (*Linognathus vituli*).

421. SELECTED ARTHROPOD PESTS: PLANTS AND PLANT PRODUCTS

Destructive stages of arthropods are indicated by the following symbols associated with the arthropod nomenclature: [A] = adult; [I] = immature; [N] = nymph; [L] = larva. Control measures, described in footnotes, should be used with great caution as many of these pesticides are extremely hazardous.

Arthropod	General Distribution	Host	Destructive Activity
Crustacea			
1 Sowbug or pillbug (<i>Porcellio laevis</i>), [A, I]	World-wide.	Vegetables, ornamentals.	Chews roots, growths near ground. ¹
2 Sowbug (<i>Cylisticus convexus</i>), [A, I]		Greenhouse seedlings.	Chews tender roots. ²
Arachnida			
3 Mite, bulb (<i>Rhizoglyphus echinopus</i>), [A, I]	N. America, Europe, Asia.	Ornamental bulbs, onion.	Bores into bulbs.
4 Mite, clover (<i>Bryobia praetiosa</i>), [A, I]	N. America.	Trees, grasses, legumes.	Sucks plant juices. ³
5 Mite, cyclamen (<i>Steneotarsonemus pallidus</i>), [A, I]	N. America, Europe.	Greenhouse ornamentals, strawberry.	Sucks plant juices, distorts buds and leaves.
6 Mite, fig (<i>Aceria ficus</i>), [A, I]		Fig.	Sucks plant juices.
7 Mite, pear leaf blister (<i>Eriophyes pyri</i>), [A, I]	All pear-growing regions.	Pear, apple.	Sucking causes blisters underside of leaves.
8 Mite, 2-spotted spider- (<i>Tetranychus telarius</i>), [A, I]	U.S.A., Europe, Africa, Asia, Australia.	Cultivated plants.	Sucks plant juices, causing loss of vigor, dropping of leaves. ³
9 Mite, spider (<i>Tetranychus</i> , other spp), [A, I]	World-wide.	Cultivated plants.	Sucks sap causing whitish blotches on plant tissues, webbing of leaves. ³

/1/ Nocturnal feeder, dependent on moist conditions. /2/ Control with DDT spray or dust. /3/ Control with phosphate and other insecticides.

421. SELECTED ARTHROPOD PESTS: PLANTS AND PLANT PRODUCTS (Continued)

Destructive stages of arthropods are indicated by the following symbols associated with the arthropod nomenclature: [A] = adult; [I] = immature; [N] = nymph; [L] = larva. Control measures, described in footnotes, should be used with great caution as many of these pesticides are extremely hazardous.

	Arthropod	General Distribution	Host	Destructive Activity
	Diplopoda			
10	Millipede, common (<i>Julus heserius</i>), [A,I]	World-wide.	Vegetables, ornamentals.	Chews young roots, stems.
11	Millipede (<i>Orthomorpha</i> spp), [A,I]		Young plants.	Chews young roots, stems.
	Symphyla			
12	Centipede, garden (<i>Scutigereilla immaculata</i>), [A,I]	N. and S. America, Europe, Africa.	Garden plants, flowers.	Chews tender plants, rootlets. ⁴
	Insecta			
13	Ant, cornfield (<i>Lasius alienus americanus</i>) [A]	U.S.A.	Corn.	Symbiotic with aphids attacking corn roots.
14	Aphid, apple (<i>Aphis pomi</i>), [A,N]	N. America.	Apple.	Causes wilting. ^{3,5}
15	Aphid, cotton (<i>A. gossypii</i>), [A,N]	U.S.A.	Cotton, melons, other plants.	Causes shedding of leaves, fruit.
16	Aphid, green peach (<i>Myzus persicae</i>), [A,N]	Warm regions of world.	Many trees, shrubs.	Sucks sap from leaves, causing curling, distortion; honeydew excreted.
17	Aphid, pea (<i>Macrosiphum pisi</i>), [A,N]		Peas, clovers, alfalfa.	Transmits pea mosaic virus; sucks plant juices. ^{2,3}
18	Aphid, woolly apple (<i>Eriosoma lanigerum</i>), [A,N]	N. and S. America, Europe, S. Africa, Asia, Australia.	Apple, pear, elm.	Sucks sap from roots, branches, causing deformed twigs, knotty roots, stunting. ⁵
19	Appleworm or codling moth (<i>Carpocapsa pomonella</i>), [L]	All apple areas.	Apple, pear, walnut, others.	Burrows into fruit, destroying or reducing value. ²
20	Armyworm (<i>Pseudoletia unipuncta</i>), [L]	World-wide.	Grains, grasses, some legumes.	Devours foliage.
21	Bagworm (<i>Thyridopteryx ephemerae formis</i>), [L]	Eastern U.S.A.	Cedar, other trees.	Devours foliage. ⁶
22	Bee, leaf-cutter (<i>Megachile latimanus</i>), [A]	World-wide.	Various trees.	Cuts off leaf fragments for nests. ²
23	Beetle, Black Hills (<i>Dendroctonus ponderosae</i>), [A,L]	Rocky Mountain regions.	Ponderosa, lodgepole, limber and white bark pines.	Bores into bark and cambial region; may girdle and kill tree.
24	Beetle, blister (<i>Epicauta vittata</i>), [A]	World-wide.	Potato, legumes.	Devours plants. ²
25	Beetle, Colorado potato- (<i>Leptinotarsa decemlineata</i>), [A,L]	N. America, Europe.	Potato, tomato, tobacco, eggplant, solanaceous plants.	Devours leaves, terminal growth. ²
26	Beetle, confused flour- (<i>Tribolium confusum</i>), [A,L] ⁷	World-wide.	Flour, grain products.	Infests and contaminates flour, mixes, bread.
27	Beetle, dried fruit (<i>Carpophilus hemipterus</i>), [L]		Dried fruit.	Destroys dried fruit.
28	Beetle, drugstore (<i>Stegobium paniceum</i>), [A,L]		Dried vegetables.	Destroys dried vegetables.
29	Beetle, Engelmann spruce (<i>Dendroctonus engelmanni</i>), [L]	Western U.S.A.	Engelmann spruce, Colorado blue spruce, lodgepole pine.	Bores into bark and cambial region; may girdle and kill tree.
30	Beetle, flea (<i>Altica</i> , <i>Epitrix</i> , <i>Phyllotrata</i> spp), [A,L] ⁸	World-wide.	Vegetable crops.	Adult holes leaves; larva often feeds on roots.
31	Beetle, grain (<i>Caulophilus latinasus</i>), [A,L]		Stored grain.	Destroys grain.
32	Beetle, green June- (<i>Cotinis nitida</i>), [A,L]		Cultivated plants (sap, fruit juices).	Destroys certain fruits; larva feeds on roots.
33	Beetle, Japanese (<i>Popillia japonica</i>), [A,L] ⁹	Eastern U.S.A., Japan, China.	Fruit trees, ornamentals, vegetables, grasses.	Destroys turf, foliage, blossoms, fruit. ²
34	Beetle, lesser grain borer (<i>Rhyzopertha dominica</i>), [A,L]		Grain flour, wood-pulp paper.	Destroys.
35	Beetle, Mexican bean- (<i>Epilachna varivestis</i>), [A,L]	U.S.A., Mexico.	Bean, soybean, cowpea, other legumes.	Devours leaves, pods, stems. ¹⁰
36	Beetle, mountain pine (<i>Dendroctonus monticolae</i>), [A,L]	Western U.S.A.	Western, lodgepole, sugar, ponderosa, white bark, and limber pines.	Bores into bark and cambial region; may girdle and kill tree.
37	Beetle, rhinoceros (<i>Dynastes tityus</i>), [A]		Ash.	Shreds bark.
38	Beetle, saw-toothed grain- (<i>Oryzaephilus surinamensis</i>), [A,L]	World-wide.	Grain, grain products, dried fruit.	Infests and devours grain, grain products, dried fruit.
39	Beetle, smaller European elm bark- (<i>Scolytus multistriatus</i>), [A]		Elm.	Vector of Dutch elm disease fungus.
40	Beetle, snout, or plum curculio (<i>Conotrachelus nenuphar</i>), [A,L]	Eastern U.S.A., and Canada.	Plum, apple, peach, cherry, deciduous stone fruits.	Adult punctures; larva feeds within and destroys fruit. ^{3,11}
41	Beetle, southern pine (<i>Dendroctonus frontalis</i>), [A,L]		Pine.	Bores into bark and cambial region; may girdle and kill tree.
42	Beetle, spotted cucumber- (<i>Diabrotica undecimpunctata</i>), [A,L]		Corn, cucurbits, weeds, grasses, other plants.	Larva feeds on roots, adult devours foliage. ¹²
43	Beetle, striped cucumber- (<i>Acalymma vittata</i>), [A,L]	N. America.	Cucurbits.	Adult devours leaves, shoots, blossoms, damages fruit; larva attacks underground parts. ¹³
44	Beetle, tobacco flea- (<i>Epitrix hirtipennis</i>), [A]	World-wide.	Tobacco.	Devours leaves especially of young plants. ²
45	Beetle, tuber flea- (<i>E. tuberis</i>), [A,L]		Potato.	Adult devours foliage; larva feeds on roots, tubers.
46	Beetle, western pine (<i>Dendroctonus brevicornis</i>), [A,L]	Western U.S.A.	Ponderosa and coulter pines.	Kills pine trees.
47	Bollworm, cotton, or corn earworm. (<i>Heliothis zea</i>), [L]	World-wide.	Cotton, corn, tomato, alfalfa, other plants.	Bores into and feeds on bolls, ears, buds; stunts plants, reduces yield. ²
48	Bollworm, pink (<i>Pectinophora gossypiella</i>), [L]	Southern U.S.A., S. America, Africa, Europe, Asia, Australia.	Cotton, okra, other malvaceous plants.	Bores into and feeds on squares and bolls, cutting fiber, reducing yield.
49	Borer, currant (<i>Ramosia tulipiformis</i>), [L]	N. America, Asia, Europe, Australia.	Currant, gooseberry, black elder, sumac.	Burrows through canes.

/2/ Control with DDT spray or dust. /3/ Control with phosphate and other insecticides. /4/ Control by treating soil with DDT, chlordane. /5/ Control with demeton, malathion, or nicotine sprays. /6/ Remove bags by hand in winter; control with lead arsenate sprays. /7/ Another important species is the red flour beetle (*T. castaneum*). /8/ Overwinters as adult. /9/ Other important June beetles belong to *Melolontha*, *Polyphylla* and *Phyllophaga* spp. /10/ Control with malathion or rotenone dusts, sprays. /11/ Control with dieldrin sprays. /12/ Vector of (a) bacterial wilt of cucurbits, (b) virus of yellow disease of asters. /13/ Vector of bacterial wilt of cucurbits; control with methoxychlor.

421. SELECTED ARTHROPOD PESTS: PLANTS AND PLANT PRODUCTS (Continued)

Destructive stages of arthropods are indicated by the following symbols associated with the arthropod nomenclature: [A] = adult; [I] = immature; [N] = nymph; [L] = larva. Control measures, described in footnotes, should be used with great caution as many of these pesticides are extremely hazardous.

Arthropod	General Distribution	Host	Destructive Activity
Insecta (continued)			
50 Borer, flat-headed apple tree- (<i>Chrysobothris femorata</i>), [L]	U.S.A., Canadian fruit-growing areas.	Fruit trees, many shade trees.	Bores into trunk of weakened trees, branches, twigs; kills trees. ¹⁴
51 Borer, peach tree (<i>Sanninoidea exitiosa</i>), [L]	All peach-growing areas.	Peach, other stone-fruit trees.	Bores in trunk at ground-level roots, girdles tree trunk, kills trees. ²
52 Borer, round-headed apple tree- (<i>Saperda candida</i>), [L]	Eastern U.S.A., Canada.	Apple, pear, quince trees.	Bores into trunk.
53 Borer, squash vine (<i>Melittia cucurbitae</i>), [L]		Squash, pumpkin, cucumber, melons.	Bores into and may girdle vine.
54 Borer, sugar cane (<i>Diatraea saccharalis</i>), [L]		Sugarcane, rice, corn, sorghums, wild grasses.	Causes dead hearts in young plants, dead tops in older plants, broken-over stalks, loss in weight and sucrose, injury to seed cane.
55 Budworm, spruce (<i>Choristoneura fumiferana</i>), [L]	Northern U.S.A., Canada.	Fir, spruce, hemlock, larch, white pine.	Causes partial to complete defoliation.
56 Bug, box elder (<i>Leptocoris trivittatus</i>), [A, I, N, L]		Box elder.	Sucks plant juices.
57 Bug, chinch (<i>Blissus leucopterus</i>), [A, N]	N. America.	Corn, grains, grasses.	Sap sucking causes wilting, death. ¹⁵
58 Bug, 3-cornered alfalfa- (<i>Spissistilus festinus</i>), [A]	World-wide.	Alfalfa.	Stunting. ¹⁶
59 Bug, harlequin cabbage- (<i>Murgantia histrionica</i>), [A, N]	Southern U.S.A., Mexico, C. America.	Cabbage, related crops, other plants.	Sap sucking causes plants to wilt, brown, and die.
60 Bug, lace (<i>Corythucha arcuata</i>)	World-wide.	Various trees, shrubs.	Speckling of leaves, stunting. ¹⁷
61 Bug, squash (<i>Anasa tristis</i>), [A, N]	N. and C. America.	Squash, other cucurbits.	Sap sucking causes plants to wilt and die.
62 Bug, tarnished plant (<i>Lygus lineolaris</i>), [A, N]	N. America.	Many plants, trees.	Leaf sucking and toxins cause bud drop, distortion, stunting. ¹⁷
63 Butterfly, monarch (<i>Danaus plexippus</i>), [L]		Milkweeds.	Feeds on host.
64 Cabbageworm, imported (<i>Pieris rapae</i>), [L]	N. America, Asia, Australia, Europe.	Cabbage, other crucifers.	Devours foliage. ^{10, 17}
65 Cadelle (<i>Tenebroides mauritanicus</i>), [A, L]	World-wide.	Stored grain, grain products.	Infests, destroys grain, grain products.
66 Cankerworm, spring (<i>Paleacrita vernata</i>), [L]	Eastern U.S.A., Canada.	Fruit and shade trees.	Defoliates trees in spring. ²
67 Caterpillar, eastern tent- (<i>Malacosoma americanum</i>), [L]	U.S.A. east of Rocky mountains.	Wildcherry, apple trees.	Defoliates trees in spring, early summer. ²
68 Caterpillar, forest tent- (<i>M. disstria</i>), [L]	N. America.	Aspen, sugar maple, oak, birch, basswood, ash, gum, other trees.	Defoliates trees in summer. ²
69 Chafer, rose (<i>Macrodactylus subspinosus</i>), [A]		Rose, grape, other bushes, vines.	Destroys blossoms, leaves, fruit. ²
70 Cicada, periodical (<i>Magicicada septendecim</i>), [A]	Eastern and southern U.S.A.	Many deciduous trees, shrubs.	Oviposition punctures injure or kill twigs. ¹⁸
71 Cornborer, European (<i>Pyrausta nubilalis</i>), [L]	Eastern U.S.A., Europe, Asia.	Corn main host; also many vegetables, weeds, ornamentals.	Bores into stalks, ears, causing breakage, reduced yield and quality. ¹⁹
72 Cricket, field (<i>Gryllus spp.</i>), [A, N]	N., C., and S. America.	Hay crops, cotton, linen.	Devours hay, plants, cotton, linen. ²⁰
73 Cricket, Mormon (<i>Anabrus simplex</i>), [A, N]	Western U.S.A.	Hay, grain, many plants.	Devours hay, grain, leaves, of plants. ²⁰
74 Cutworm, variegated (<i>Peridroma margaritosa</i>), [L]	World-wide.	Many plants.	Cuts down seedlings, transplants. ²¹
75 Earwig, European (<i>Forficula auricularia</i>)	World-wide.	Growing plants, stored grain, decayed vegetation.	Chewing.
76 Flea, Lucerne (<i>Sminthurus viridis</i>), [A, I]	Europe, Australia.	Legumes.	Surface feeding causes scorching of leaves.
77 Fly, bulb (<i>Lampetia equestris</i>), [L]	Europe, N. America.	Narcissus, other bulbs.	Bores into bulbs.
78 Fly, carrot rust (<i>Psila rosae</i>), [L]	Europe, northern N. America.	Carrot, celery, umbelliferous plants.	Bores into and eats fibrous roots. ²²
79 Fly, frit (<i>Oscinella frit</i>), [L]	N. America, Europe, Asia.	Cereals, grasses.	Bores into stems, eats central shoots.
80 Fly, hessian (<i>Phytophaga destructor</i>), [L]	Europe, Asia, N. America, New Zealand.	Wheat, barley, rye.	Feeds on stems, causing breaking and stunting. ²³
81 Fly, Mediterranean fruit (<i>Ceratitis capitata</i>), [A, L]	Mediterranean region, Hawaii, S. Africa, S. America, western Australia.	Fruits, vegetables.	Adult makes egg punctures, larva burrows through fruit. ²⁴
82 Fly, vinegar fruit- or vinegar gnat (<i>Drosophila melanogaster</i>), [L]	World-wide.	Ripe or decaying fruit.	Larva breeds in ripe fruit.
83 Fruitworm, tomato (<i>Heliothis zea</i>) [L]		Tomato, corn, cotton, bean.	Feeds in fruit. (See Bollworm, cotton.)
84 Grasshopper, red-legged (<i>Melanoplus femur-rubrum</i>), [A, N]	World-wide.	Hay crops, range, pasture.	Devours hay, grasses, vegetation. ²⁵
85 Grasshopper, migratory- (<i>M. mexicanus</i>), [A, N]	Western N. America.	Crops, grasses.	Devours hay, grasses, legumes, cotton. ²⁵
86 Greenbug (<i>Toxoptera graminum</i>), [A, N]		Barley, oats, wheat, small grains.	Sap sucking causes leaves to wither, yellow; plants die. ²⁶
87 Hornworm, tobacco (<i>Protoparce sexta</i>), [L]	U.S.A., Canada.	Tobacco, tomato, eggplant, pepper, potato.	Devours foliage. ²⁷

/2/ Control with DDT spray or dust. /10/ Control with malathion or rotenone dusts, sprays. /13/ Vector of bacterial wilt of cucurbits; control with methoxychlor. /14/ Control by wrapping trunks of young trees with paper for first year. /15/ Control with dieldrin barriers. /16/ Control with methoxychlor. /17/ Control with DDT, aldrin, dieldrin, toxaphene, heptachlor. /18/ Control with TEPP. /19/ Control with DDT, Ryania, culture methods. /20/ Control with poison bran bait containing fluosilicate, aldrin, chlordane, heptachlor, or toxaphene. /21/ Control with toxaphene. /22/ Control by treating soil with aldrin, dieldrin, etc. /23/ Control by planting after "free fly" dates, and by planting resistant varieties. /24/ Control with malathion bait or spray. /25/ Control with aldrin, chlordane, heptachlor in dusts, sprays, baits. /26/ Control with parathion spray. /27/ Control with TDE, endrin.

421. SELECTED ARTHROPOD PESTS: PLANTS AND PLANT PRODUCTS (Continued)

Destructive stages of arthropods are indicated by the following symbols associated with the arthropod nomenclature: [A] = adult; [I] = immature; [N] = nymph; [L] = larva. Control measures, described in footnotes, should be used with great caution as many of these pesticides are extremely hazardous.

Arthropod	General Distribution	Host	Destructive Activity
Insecta (continued)			
88 Hornworm, tomato (Protoparce quinquemaculata), [L]	N. and S. America, Europe, Hawaii.	Tomato, tobacco, other solanaceae.	Devours foliage.
89 Jointworm, wheat (Harmolita tritici), [L]	Eastern and central U.S.A.	Wheat, some grasses.	Causes galls in wheat, breaking of stems. ²⁸
90 Katydid, broad-winged (Microcentrum rhombifolium), [A, N]	N. America.	Many broad-leaved trees, shrubs.	Chews leaves.
91 Leafhopper, beet (Circulifer tenellus), [A]		Sugar beet, bean.	Vector of curly top disease of beets (virus).
92 Leafhopper, potato (Empoasca fabae), [A, N]	N. and S. America.	Potato, alfalfa, bean, celery, other plants.	Leaf sucking causes wilting, drying of leaves, stunting. ^{2, 29}
93 Leafworm, cotton (Alabama argillacea), [L]	N. and S. America.	Cotton only.	Devours leaves. ²
94 Locust, desert (Schistocerca gregaria), [A, N] ³⁰	India, Iran, Arabia, N. Africa.	Many plants.	Chews leaves.
95 Louse, book (Liposcelis divinatorius), [A, I]	World-wide.	Cereals, vegetables.	Contaminates food, destroys book bindings.
96 Maggot, apple (Rhagoletis pomonella), [L]	North eastern and north central U.S.A.	Apple, blueberry.	Bores into and destroys fruit. ²
97 Maggot, cabbage root (Hylemya brassicae), [L]	Northern U.S.A.	Cabbage, many other plants.	Bores into roots. ²²
98 Maggot, onion (H. antiqua), [L]	Europe, N. America.	Onion, garlic.	Mines out bulbs. ³¹
99 Maggot, seed-corn (H. clicurra), [L]		Corn, bean, other plants.	Devours seed.
100 Mealworm (Tenebrio molitor), [L]		Grain products and refuse.	Destroys grain, grain products.
101 Mealworm, dark (T. obscurus), [L]		Grain products and refuse.	Destroys grain, grain products.
102 Mealybug (Pseudococcus citri), [A, N]	Tropical and sub-tropical areas.	Citrus, ornamental plants.	Sap sucking causes plants to die back. ³²
103 Moth, Angmois grain (Sitotroga cerealella), [L]		Grain feed.	Destroys grain feed in storage.
104 Moth, codling (Carpocapsa pomonella), [L]	Apple growing regions of N. and S. America, Europe, Asia, S. Africa, S. Australia.	Apple, pear, quince, walnut, apricot, similar fruits.	Bores into and destroys fruit, or reduces its value. ²
105 Moth, diamondback (Plutella maculipennis), [L]	World-wide.	All cruciferous plants.	Eats small holes in outer leaves.
106 Moth, European pine shoot- (Rhyacionia buoliana), [L]		Red, Scotch, mugho pines.	Kills buds, twigs.
107 Moth, grape berry (Paralobesia viteana), [L]	Eastern half U.S.A.	Grape.	Destroys berries. ^{2, 26}
108 Moth, gypsy (Porthetria dispar), [L]	Northeastern U.S.A., Europe, Asia.	Most deciduous and evergreen trees, shrubs.	Devours leaves.
109 Moth, Indian meal- (Plodia interpunctella), [L]	World-wide.	Grain, grain products, dried fruit, nuts.	Destroys and webs grain, grain products; infests fruit, nuts.
110 Moth, Mediterranean flour (Anagasta kuhniella), [L]		Mill products.	Destroys grain products.
111 Moth, Oriental fruit (Grapholitha molesta), [L]	N. America, Europe, Asia.	Peach, quince, apple.	Tunnels twigs, destroys fruit value. ^{2, 26}
112 Phylloxera, grape (Phylloxera vitifoliae), [A, N]	N. America, Europe.	Grape vines.	Root and leaf sucking causes galls, eventual death of vines. ³³
113 Pickleworm (Diaphania nitidalis), [L]	Southern U.S.A., West Indies.	Cucumber, squash, melons.	Feeds on surface, bores into flowers, buds, fruit, stalks, vines.
114 Psylla, pear (Psylla pyricola), [A, N]	Europe, U.S.A.	Pear.	Leaf sucking, causing leaf drop. ^{32, 26}
115 Roller, red-banded leaf- (Argyrotaenia velutinana), [L]	U.S.A.	Apple, peach; other trees, shrubs.	Devours foliage, scars fruit.
116 Sawfly, European spruce (Diprion hercyniae), [L]	Europe, northeastern U.S.A., Canada.	Spruce.	Devours leaves.
117 Sawfly, European wheat stem (Cephus pygmaeus), [L]	Northeastern U.S.A., Europe, Near East.	Wheat, rye, barley, timothy, other grasses.	Larva mines stems; causing breakage.
118 Sawfly, wheat stem (C. cinctus), [L]		Wheat, grasses.	Larva tunnels stems, cause breaking, reduced grain yield.
119 Scale, San Jose (Aspidiotus perniciosus), [A, N]	World-wide	Deciduous fruit trees, ornamentals.	Secreted toxins cause wilting, kill infested trees. ³⁴
120 Scale, soft brown (Coccus hesperidum), [A, N]	World-wide in green-houses (subtropical spp).	Citrus, ornamentals.	Sap sucking causes plants to die back. ³²
121 Silverfish (Lepisma saccharina), [A, I] ³⁵	World-wide.	Starchy substances.	Devours book bindings, fabrics, wallpaper.
122 Slug, rose (Cladius isomerus), [L]	World-wide.	Rosebush.	Skeletonizes and causes browning of leaves. ³⁶
123 Spittlebug, meadow (Philaenus leucophthalmus), [N]	Eastern U.S.A.	Legumes, hay crops.	Sucks plant juices, causing wilting, stunting, reduced forage yield. ³⁷
124 Termite, eastern subterranean- (Reticulitermes flavipes), [A, N]	Eastern U.S.A.	Wood, dead wood, cellulose products.	Riddles, weakens, destroys wood and cellulose materials. ³⁸
125 Thrips, gladiolus (Taeniothrips simplex), [A, N]		Gladiolus, iris, lily.	Attacks flowers, foliage, causing silvering, browning, and distortion of leaves.
126 Thrips, onion (Thrips tabaci), [A, N, L]	N. and S. America, Europe, Asia, S. Africa, Australia.	Onion, bean, cabbage, tomato, cotton.	Sucks plant juices, causing leaves and buds to pucker and silver. ¹⁷
127 Thrips, pear (Taeniothrips inconsequens), [A, N]		Pear, plum, prune.	Deforms buds, scars fruit, injures foliage.
128 Wasp, oak gall or apple (Amphibolips confluenta), [L]	World-wide.	Oak.	Causes galls on oak leaves. ³⁹

/2/ Control with DDT spray or dust. /17/ Control with DDT, aldrin, dieldrin, toxaphene, heptachlor. /22/ Control by treating soil with aldrin, dieldrin, etc. /26/ Control with parathion spray. /28/ Control by burning stubble, crop rotation. /29/ Transmits hopperburn disease. /30/ Has a migratory phase. /31/ More serious under wet and cool conditions. /32/ Honeydew is formed or excreted. /33/ Control by using resistant root stocks. /34/ Control by oil emulsion sprays in dormant stage, malathion sprays in summer. /35/ Another species is the firebrat (Thermobia domestica). /36/ Control by spraying undersides of leaves with malathion. /37/ Control with lindane, methoxychlor sprays. /38/ For protection of new structures, control by treating adjacent infested soil with DDT, chlordane, dieldrin. /39/ Control by burning leaves in winter.

421. SELECTED ARTHROPOD PESTS: PLANTS AND PLANT PRODUCTS (Concluded)

Destructive stages of arthropods are indicated by the following symbols associated with the arthropod nomenclature: [A] = adult; [I] = immature; [N] = nymph; [L] = larva. Control measures, described in footnotes, should be used with great caution as many of these pesticides are extremely hazardous.

Arthropod	General Distribution	Host	Destructive Activity
Insecta (concluded)			
129 Webworm, fall (<i>Hyphantria cunea</i>), [L]	U.S.A., southern Canada.	Broad leaf fruit, shade and nut trees.	Webbs branches, devours foliage. ²
130 Weevil, alfalfa (<i>Hypera postica</i>), [L]		Alfalfa.	Skeletonizes growing plant tips and leaves, making hay unpalatable as livestock feed.
131 Weevil, bean (<i>Acanthoscelides obtectus</i>), [L]	World-wide	Bean, pea, cowpea.	Devours inside of bean in field and storage.
132 Weevil, boll (<i>Anthonomus grandis</i>), [A, L]	Southern U.S.A., Mexico.	Cotton	Destroys buds, devours squares and bolls. ⁴⁰
133 Weevil, cowpea (<i>Callosobruchus maculatus</i>), [L]		Dried peas.	Destroys peas.
134 Weevil, pea (<i>Bruchus pisorum</i>), [L]	World-wide.	Pea.	Feeds within pea seeds.
135 Weevil, granary (<i>Sitophilus granarius</i>), [A, L]		Grain, grain products.	Destroys grain.
136 Weevil, rice (<i>S. oryza</i>), [A, L]	World-wide.	Stored grains, cereal products.	Larva grows in kernels, destroys stored grain.
137 Weevil, sweetpotato (<i>Cylas formicarius elegantulus</i>), [A, L]	Southern U.S.A., other areas.	Sweetpotato, morning glory.	Adult feeds on leaves, vines, roots; larva in stems, roots, potato.
138 Weevil, white pine (<i>Pissodes strobi</i>), [L]	U.S.A., southern Canada.	Pine, Norway spruce.	Kills terminal growth; degrades lumber.
139 Whitefly, greenhouse (<i>Trialeurodes vaporariorum</i>), [N]	World-wide.	Most plants.	Leaf sucking causes wilting. ³²
140 Wireworm, Pacific Coast (<i>Limoni- canus</i>), [L]	Rocky Mountains.	All vegetables and feed crops.	Destroys seeds, cuts underground stems, bores into roots, stems, tubers.
141 Wireworms (<i>Agriotes</i> , <i>Limoni- us</i> , <i>Melanotus</i> , <i>Horistonotus</i> spp), [L]	World-wide.	Truck, cereal and forage crops.	Devours or bores into roots, seeds. ⁴¹
142 White grubs, or June beetles (<i>Phyllophaga fusca</i> , other <i>Phyllophaga</i> spp), [A, L]		Most plants.	Devours roots, underground parts; adult defoliates trees. ¹⁷

/2/ Control with DDT spray or dust. /17/ Control with DDT, aldrin, dieldrin, toxaphene, heptachlor. /32/ Honeydew is formed or excreted. /40/ Control by spraying or dusting with calcium arsenate, BHC, toxaphene, endrin, dieldrin, aldrin. /41/ Control corn wireworm (*Melanotus* sp) of U.S.A. by treating soil with DDT, chlordane, dieldrin, heptachlor.

422. SELECTED DISEASE VIRUSES: ANIMALS AND BACTERIA

Entries in parentheses include either scientific equivalents of common names, or questionable or unconfirmed reports. Abbreviations: Agglut.=agglutinates; antig.=antigenically; c=centrifugation; CNS=central nervous system; CSF=cerebrospinal fluid; dm=direct microscopy; em=electron microscopy; enceph.=encephalitis; g.pig=guinea pig; l.n.=lymph node(s); mf=membrane filtration; NP=nasopharyngeal; RBC=red blood cells; resp.=respiratory.

Common Name	Scientific Name	Natural Host	Location in Body in Natural Infection	Natural Transmission	Experimental Host	Growth in Egg	Tissue Culture	Estimated Size μ m	Remarks
1 Abortion, equine	Tortor equae	Horse.	Fetus; fetal membranes.	Contact; lining from contaminated stalls.	Pregnant g.pig, hamster, equine fetus.	+	Fetal equine spleen; cat lung.	Passes Seitz.	Antig. related to equine influenza.
2 Abortion, sheep		Sheep.	Fetal membranes, uterine discharge.	(Ingestion).	Cattle, mouse, g. pig.	+		(Over 400 [mf]).	Psittacosis group.
3 Adenoidal-pharyngeal-conjunctivitis		Man.	Pharynx; NP discharges; conjunctiva.	Conjunctival and NP discharges.			Human adenoid, tumor; monkey kidney.		Several antigenic types.
4 Anemia, equine, infectious	Trifur equorum.	Man, horse, donkey.	Blood, (all secretions, excretions).	Contact (ingestion, milk, flies).	Rabbit, swine, rat, mouse			11-59[em].	

422. SELECTED DISEASE VIRUSES: ANIMALS AND BACTERIA (Continued)

Entries in parentheses include either scientific equivalents of common names, or questionable or unconfirmed reports. Abbreviations: Agglut.=agglutinates; antig.=antigenically; c=centrifugation; CNS=central nervous system; CSF=cerebrospinal fluid; dm=direct microscopy; em=electron microscopy; enceph.=encephalitis; g. pig=guinea pig; l.n.=lymph node(s); mf=membrane filtration; NP=nasopharyngeal; RBC=red blood cells; resp.=respiratory.

Common Name	Scientific Name	Natural Host	Location in Body in Natural Infection	Natural Transmission	Experimental Host	Growth in Egg	Tissue Culture	Estimated Size μ m	Remarks
5 Bacteriophages: Coli (T)		Escherichia coli, strain B.						15-150[em].	4 antigenic groups, 7 phages.
6 Coli-dysentery group		E. coli, Shigella dysenteriae.						8-75[mf].	Several antigenic types, plaques.
7 Megatherium		Bacillus megatherium.			Mutants of Bacillus megatherium.			30-45[mf]; 30-37[c].	
8 Staphylococcus (Kreuger)		Micrococcus pyogenes var. aureus.						50-75[mf]; 60-70[c].	3 antigenic types, plaques.
9 Typhoid V (Q151)		Salmonella typhosa.						Passes EK Seitz.	Acts on V component of cells.
10 B virus	Scelus beta.	Monkey, (man?).	CNS, spleen, saliva.	Bite.	Rabbit, g. pig.	+	Monkey, kidney	125[mf].	Herpes-pseudorabies group.
11 Blue tongue	Tortor ovis.	Sheep, cattle.	Blood, all organs.	Midges (Culicoides).	Goat, hamster ² , mouse ² .	+		100-150[mf].	(Several antigenic types).
12 Borna disease	Erro bor-nensis.	Horse, sheep, cattle.	CNS, pancreas, saliva, nasal secretions.	Ingestion, contact.	Rabbit, g. pig, rat, mouse, monkey, chicken.			85-125[mf].	Reddish intranuclear inclusions--Type B.
13 Bwamba fever	Smith-burnia bwamba.	Man.	Blood.		Monkey, mouse.	+		75-113[mf].	
14 Chickenpox (varicella)	Briareus vari-cellae.	Man.	Fluid, crusts of cutaneous lesions.	Air-borne, contact.			Human foreskin, embryo.	210-243[em].	Antig. related to herpes zoster.
15 Choriomen-ingitis, lymphocytic	Armillilia erebea.	Man, "house mouse."	Blood, CSF, urine, NP secretions, CNS.	(Urine of infected mice).	Mouse, g. pig, monkey.	+	Mouse brain, chick embryo.	37-55[c]; 40-60[mf].	
16 Colorado tick fever	Sabinia coloradensis.	Man, tick.	Blood.	Tick (Dermacentor).	Hamster, mouse.	+		35-50[mf].	
17 Common cold	Tarpeia premens.	Man.	Respiratory tract.	NP discharges.	Chimpanzee, (man).		Human embryo lung.	30-70[mf].	
18 Contagious ecthyma	Hostis ecthymatis.	Man, sheep, goat.	Lesions of lips, eyelids, nose, mouth.	Contact, through abraded epith.				Passes V Berkefeld.	
19 Coxsackie	Daldorfia coxsackie.	Man, rabbit (cottontail).	Intestinal contents.	Ingestion.	Mouse ² , hamster, + monkey, chimpanzee.	+	Newborn, embryonic mouse ³ .	37[em].	16 or more antigenic types.
20 Dengue	Sabinia ashburnii.	Man, monkey.	Blood.	Mosquito (Aedes).	Mouse, hamster ² .	+		17-25[mf].	2 antigenic types.
21 Distemper, canine	Tarpeia canis.	Dog, ferret, other carnivores.	Blood, secretions, excretions.	Contact, secretions, excretions.	Ferret; mouse ² , hamster.	+	Dog kidney.	20-22[em].	Classical, neurotrophic, hard pad types.
22 Distemper, feline	Tarpeia felis.	Cat, other Felidae.	All tissues, secretions, excretions.	Same as dog distemper.	(Cat).			Passes N Berkefeld.	Antig. diff. from dog distemper.
23 Durand disease		Man.	Blood, spleen, urine, CSF, intestinal contents.		Hamster, g. pig., dog, monkey, cat.	+	Chick embryo.	40-80[mf].	
24 Encephalitis, California	Rocaea hammonii.	(Man, horse, ground squirrel).		(Mosquito (Aedes, Culex)).	Mouse, cotton rat, hamster.	+		60-125[mf].	Antig. related to St. Louis enceph. group.
25 Encephalitis, eastern equine	Erro tenbroeckii.	Man, horse, birds.	CNS, blood, spleen.	Mosquito (Mansonia), (mites).	Mouse, many domestic and wild animals, birds.	+	Chick embryo, rat.	25[mf]; 40[c, em].	Antigenically distinct.
26 Encephalitis, Venezuelan equine	Erro venezuelensis.	Man, horse, mule.	CNS, blood, nasopharynx.	Mosquito (Aedes, Mansonella).	Mouse, g. pig, rabbit, rat, dog, sheep, goat.	+	Mouse, human embryo	Passes N Berkefeld.	
27 Encephalitis, western equine	Erro equinus.	Man, horse, mule; wild, domestic birds.	CNS, blood, spleen.	Mosquito (Culex), (mites).	Mouse, many domestic and wild animals.	+	Chick embryo.	25[mf]; 40[c, em].	Antigenically distinct.
28 Encephalitis, Japanese	Erro japonicus.	Man, horse, cattle, goat, (some wild birds).	CNS, blood.	Mosquito (Culex).	Mouse, hamster, monkey, domestic animals.	+	Chick embryo, mouse, rabbit.	20-30[mf]; 10 or less [c].	Antig. related to St. Louis enceph. group; agglut. RBC.
29 Encephalitis, Russian Far East ⁴	Erro silvestris.	Man, squirrel, hedgehog.	CNS, blood, CSF, NP secretions, urine.	Tick (Ixodes persulcatus).	Mouse, hamster, monkey, sheep, wild birds.		Mouse, chick embryo, mouse tumor.	15-25[mf].	Antig. related to louping-ill; agglut. RBC.
30 Encephalitis, St. Louis	Erro scelestus.	Man, chicken, other birds.	CNS, blood.	Mosquito, (Culex), (mites).	Mouse, monkey.	+	Mouse, chick embryo.	22-33[mf].	Antig. related to Japanese-West Nile group; agglut. RBC.
31 Encephalomyelitis, avian	Erro gallinae.	Chicken, pheasant.	Brain, liver, spleen.	Possibly by contact and through egg).	Young turkey, pigeon, duck.		Chick embryo.	20-30[mf].	
32 Encephalomyelitis, muris, mouse, (Theiler)	Legio muris.	Mouse.	CNS, blood, intestinal contents.	Ingestion of feces.	Cotton rat, virus-free mice.	+	Chick, mouse embryo.	9-13[mf]; 15x115[em].	2 antigenic types; agglut. RBC.
33 Encephalomyocarditis		Monkey, mon-goose, wild rodents.	CNS, blood.	(Mosquito (Taeniorhynchus).	Mouse, hamster, g. pig, monkey, cotton rat.	+	Mouse, chick embryo.	8-15[mf]; 25-30[em].	4 antigenic types; agglut. RBC.
34 Exanthema subitum ⁵	Morbillifex subitus.	Man.	Blood, upper resp. tract (feces).		Monkey.		(Human embryo).	Passes Seitz.	

/1/ Only by laboratory infection. /2/ Suckling. /3/ Also chick, human, monkey embryo. /4/ Spring-summer encephalitis. /5/ Roseola infantum.

422. SELECTED DISEASE VIRUSES: ANIMALS AND BACTERIA (Continued)

Entries in parentheses include either scientific equivalents of common names, or questionable or unconfirmed reports. Abbreviations: Agglut.=agglutinates; antig.=antigenically; c=centrifugation; CNS=central nervous system; CSF=cerebrospinal fluid; dm=direct microscopy; em=electron microscopy; enceph.=encephalitis; g. pig=guinea pig; l.n.=lymph node(s); mf=membrane filtration; NP=nasopharyngeal; RBC=red blood cells; resp.=respiratory.

Common Name	Scientific Name	Natural Host	Location in Body in Natural Infection	Natural Transmission	Experimental Host	Growth in Egg	Tissue Culture	Estimated Size μ m	Remarks
35 Fibroma, rabbit (Shope)	Molitor fibromatis.	Rabbit (cottontail, squirrel).	Subcutaneous nodules, skin; (blood, spleen).		Domestic rabbit, wood-chuck.	+	Rabbit testis (variant).	125-175 [mf].	Antig. related to myxoma, inflammatory variant.
36 Foot and mouth disease	Hostia pecoris.	Man, cattle, goat, sheep, swine.	Blood, saliva, milk, urine.	Contact, secretions, excretions, garbage.	Rabbit, g-pig, puppy, mouse, rat, baby chick.	+	G. pig, bovine epithelium.	8-12 [mf].	3 or more antigenic types, agglut. RBC.
37 Fowl plague	Tortor galli.	Domestic fowl, some wild birds.	Blood, secretions, excretions.	Ingestion.	Starling, canary, mouse, rat, rabbit, ferret.	+ and pigeon	Chick embryo.	60-140 [mf, c, em].	Antig. variants, agglut. RBC.
38 Fowl tumors	Molitor tumoris.	Chicken.	Any mesodermal tissue, sometimes in blood.	(Early life: upper resp.-digestive tract.)	Domestic fowl (age limitations).	+	Chick embryo, chick.	100 [mf]; 60-70 [mf, dm].	Antig. related to lymphomatosis viruses.
39 Fowl leucosis (leukemia)	Trifur gallinarum.	Chicken.	Blood, viscera.		(Chicken, turkey, pheasant, guinea fowl).			20-120 [mf]; 120 [dm].	
40 Lymphomatosis (Marek paralysis)		Chicken.	Viscera, bones, eye tissues, nasopharynx.	Through egg, in early life after hatching.	(Chicken).				
41 Gastroenteritis, human (Marcy)		Man.	Intestinal tract, resp. droplets.	Ingestion.	(Man).			Passes UF sintered glass.	Produces febrile disease.
42 Hepatitis, canine	Tortor vulpis; wolf, coyote, bear.	Dog, fox, wolf, coyote, bear.	Blood, secretions, excretions.	Ingestion, secretions, excretions.	Ferret, other carnivores	+	Dog kidney.	Passes N Berkefeld.	
43 Hepatitis, human, (infectious)	Reedella triginta.	Man.	Blood, intestinal contents.	Ingestion of infected materials.	(Man).	+	(Rabbit, chick embryo).	Passes Seitz.	Antig. distinct. Type A.
44 Hepatitis, human, (serum)	Reedella centum.	Man.	Blood.	Injection, contact with blood or derivatives.	(Man).	(+)		26 or less [mf].	Antig. distinct. Type B.
45 Hepatitis, mouse		Mouse	Blood, liver, urine, spleen, kidney, feces.		Mouse ² .		Mouse embryo.	130-180 [mf].	Several antigenic types.
46 Herpes simplex	Scelus recurrens.	Man.	Skin, cornea, blood, mucosa, CNS.	(Contact).	Rabbit, mouse.	+	Rabbit, chick embryo.	100-150 [mf].	Antig. related to B. pseudorabies.
47 Herpes zoster	Briareus zoster.	Man.	Skin, sensory nerves, ganglia.		(Man)		Human skin.	210-250 [em].	Antig. related to chickenpox.
48 Hog cholera	Tortor suis.	Swine.	Blood, all secretions, excretions.	Contact, secretions, excretions, garbage.	Rabbit, g-pig.		Swine testis, marrow, spleen.	5 [em]; 27 [em].	Antig., neurotrophic variants.
49 Inclusion conjunctivitis	Chlamydozoon oculogenitale.	Man.	Conjunctiva, (cervix, urethra).	Contact, genitalia secretions.	Baboon.			250 [dm].	
50 Influenza	Tarpeia alpha, beta, taylorii.	Man.	Respiratory tract.	Contact, NP secretions.	Ferret, mouse.	+	Chick embryo, mouse tumor.	80-120 [mf, c, em].	Antig. types A-C, agglut. RBC.
51 Influenza, equine	Tarpeia caballi.	Horse, mule.	Respiratory tract, blood, semen.	Inhalation, ingestion, contact.	(Horse).	+		Passes N Berkefeld.	Antig. related to equine abortion.
52 Influenza, swine	Tarpeia shopei.	Swine	Respiratory tract, blood.	Contact, secretions, ingestion of lungworm ova, larvae.	Ferret, mouse.	+		80-120 [mf, c].	Antig. related to type A influenza. Virus and H. suis elicit clinical disease.
53 Insect viruses: Bergoldia calyptra (Steinhaus)	Fir-shoot roller ⁷		Blood cells, (fat tissue).	Oral, (egg).				50x262 [em].	Inclusion bodies: capsular.
54 Morator nudus (Wasser)	Armyworm ⁸			Oral.				25 [em].	Inclusion bodies: none.
55 Polyhedral of Arctia villica	Cream spot tiger moth.		Hypodermis.	Oral, (egg).					Inclusion bodies: polyhedral.
56 Polyhedral of Diprion hercyniae	European spruce sawfly.		Midgut, epithelium.	Oral, (egg).				50x250 [em].	Inclusion bodies: polyhedral.
57 Silkworm jaundice	Borrelina bombycis. (Bombyx mori).	Silkworm	Fat, hypodermis, blood cells, (other tissues).	Oral, (egg).	(Gypsy moth; nun moth).			40x288 [em].	Inclusion bodies: polyhedral.
58 Laryngotracheitis, avian, infectious	Tarpeia avium	Chicken, pheasant.	Larynx, trachea, bronchi.	Contact.		+ and turkey.		45-85 [mf]; 100 [em].	
59 Louping ill	Erro scoticus.	Man, sheep.	CNS, blood, CSF (man).	Tick (Ixodes ricinus), contact (man).	Mouse, vole, swine, hamster, cattle, (horse).	+	Chick embryo.	15-20 [mf]; 22-27 [c].	Antig. related to Russian Far East virus.
60 Lumpy skin disease		Cattle.	Cutaneous nodules, l.n., blood, other tissues.			+		10-25 [mf].	
61 Lymphogranuloma venereum.	Miyagawana phagranulomatis.	Man.	Genital lesion, CSF, inguinal l.n.	Direct contact.	Mouse, g-pig, monkey.	+	Chick, mouse embryo, g. pig, mouse testis.	300 [dm]; 438 [em].	Antig. related to psittacosis, produces toxin.
62 Measles (rubeola)	Morbillifex morbillorum.	Man.	Blood, skin, respiratory tract.	Contact, NP discharges.	Monkey.	+	Chick embryo, human, monkey kidney.	Passes Seitz.	
63 Measles, German (rubella)	Morbillifex embryorum.	Man.	Blood, nasopharynx.	Contact, NP discharges.	(Man).			Less than 800 [mf].	

/2/ Suckling. /5/ Roseola infantum. /6/ Raw. /7/ Cacoecia murinana. /8/ Clirphis unipuncta.

422. SELECTED DISEASE VIRUSES: ANIMALS AND BACTERIA (Concluded)

Entries in parentheses include either scientific equivalents of common names, or questionable or unconfirmed reports. Abbreviations: Agglut.=agglutinates; antig.=antigenically; c=centrifugations; CNS=central nervous system; CSF=cerebrospinal fluid; dm=direct microscopy; em=electron microscopy; enceph.=encephalitis; g. pig=guinea pig; l.n.=lymph node(s); mf=membrane filtration; NP=nasopharyngeal; RBC=red blood cells; resp.=respiratory.

Common Name	Scientific Name	Natural Host	Location in Body in Natural Infection	Natural Transmission	Experimental Host	Growth in Egg	Tissue Culture	Estimated Size μ	Remarks
64 Meningo-pneumonitis		(Man, ferret)	Respiratory tract.		Mouse, ferret, monkey.	+		300-400[mf], 354[em].	Antig. related to psittacosis; produces toxin.
65 Molluscum contagiosum	Molluscum contagiosum hominis.	Man.	Skin.	Direct contact.				190-250[em].	
66 Mumps	Rubella infans.	Man.	Salivary glands, blood, gonads, CSF.	Droplets of saliva.	Monkey, hamster.	+	Chick, mouse embryo.	90-135[mf], 140-268[em].	Agglut. RBC, produces hemolysin.
67 Myxomatosis, infectious	Borrelia myxomatosis.	Domestic, wild rabbit.	Skin, mucosa, blood.	Contact, arthropods (mechanical).	Domestic, wild rabbit.	+	Rabbit, chick embryo.	286x230x75[em].	Antig. related to Fibroma (Shope).
68 Newcastle disease	Tortur furens.	Man, domestic fowl, some wild birds.	Blood, secretions, excretions (ovipara), lungs (calf).	Contact, garbage, (poultry scraps).	Common lab. animals, cattle, quail, sparrow.	+	Chick embryo.	80-100[mf].	Neural, pneumonic visceral strains, agglut. RBC.
69 Papilloma, rabbit (oral)	Molluscum gingivalis.	Domestic rabbit.	Tongue.	(Suckling).	Wild rabbit.			Passes Berkefeld.	Differs antigenically from papilloma (Shope).
70 Papilloma, rabbit (Shope)	Molluscum sylvilagi.	Rabbit (cottontail).	Skin.		Domestic rabbit, hamster.			22-35[mf], 32-50[cl].	Malignancy becomes carcinomatous.
71 Phlebotomus fever sand-fly, (pappataci fever)	Sabina doerrii.	Man.	Blood.	Midge (Phlebotomus papatasi).	Man.			40-60[mf].	2 or more antigenic types.
72 Pneumo-enteritis, bovine.	Tarpeia vitulae.	Calf.	Lungs, intestinal tract, blood.	(Contact, resp., intestinal discharges).	Mouse.			Passes N Berkefeld.	
73 Pneumonia of mice, virus		Mouse.	Lungs.	Contact, resp. excretions.	(Mouse).		Chick embryo.	100-150[mf].	Agglut. RBC.
74 Pneumonia, swine, virus		Swine.	Lungs.	Contact, resp. excretions.	(Swine).		Swine lung, kidney.	Over 200[cl].	
75 Pneumonitis, feline	Miyagawana felis.	Cat.	Respiratory tract.	Inhalation, resp. excretions.	Mouse, g. pig, rabbit, hamster.	+		423x161[em].	Antig. related to psittacosis, produces toxin.
76 Pneumonitis, mouse (Nigg)		Mouse.	Lung.		(Mouse).	+		497[em].	Member of psittacosis group.
77 Poliomyelitis	Legio debilitans.	Man.	CNS, intestinal tract, blood.		Chimpanzee, monkey, mouse, cotton rat, hamster.	+	Human, monkey.	28[em].	3 or more antigenic types.
78 Pox, cow	Borrelia jenneri.	Man, cattle.	Cutaneous lesions, teat, udder.	Contact.	Rabbit, g. pig.	+	Bovine fetus, skin.		Antig. related to vaccinia.
79 Pox, fowl	Borrelia avium.	Domestic fowl, some wild birds.	Skin lesions, blood, mucosa, viscera.	Contact, (mosquito).		+	Chick embryo, turkey.	125[mf, m], 264-322[em].	Differs antigenically from vaccinia.
80 Pox, mouse (ectromelia)	Borrelia marmorans.	Mouse (domestic).	Skin, blood, liver, spleen.	Contact.	(Mouse).	+	Mouse embryo.	210-300[em].	Antig. related to vaccinia, agglut. RBC.
81 Pseudo-rabies (D'Aujesky's disease)	Formido aueszkyi.	Cattle, sheep, swine, dog, cat, rat.	Cutaneous lesions, CNS, nasal secretions (swine).	Ingestion, contact.	Rabbit, g. pig, bat, monkey, mouse, hamster.	+	Chick embryo, rabbit, g. pig.	90-100[em].	Antig. related to herpes.
82 Psittacosis (ornithosis, inella psittacine parrot fever)	Miyagawana psittacine.	Man, psittacine birds, duck, chicken, cloacal contents.	Lung, spleen, liver, resp. secretions, droppings, contact.	Inhalation, dried secretions droppings, contact.	Mouse, g. pig, monkey.	+	Chick embryo, mouse.	455[em].	Produces toxin.
83 Rabies	Formido innoxabilis.	All mammals.	CNS, salivary, lacrimal glands, kidney, pancreas, saliva.	Saliva, through broken epithelium.	Mammals, domestic fowl.	+	Rabbit, rat, mouse, chick embryo.	100-150[mf].	
84 Rift Valley fever	Reedella vallis.	Man, sheep.	Blood, liver.	(Mosquito).	Cattle, goat, rat, monkey, mouse.	+	Chick embryo.	23-35[mf].	
85 Rinderpest	Tortur bovis.	Domestic animals, deer.	Blood, secretions, excretions.	Ingestion.	Rabbit, g. pig, Chinese pig.	+	Chick embryo.	Passes V Berkefeld.	
86 Smallpox variola	Briareus variolae (hominis).	Man, (monkey).	Lesions of skin, NP secretions, mucosa, blood.	Inhalation, secretions, scales.	Monkey, rabbit.	+		244-302[em].	Antig. related to vaccinia, agglut. RBC.
87 Stomatitis, vesicular	Hostis equinus.	Man, horse, cattle, swine.	Lesions of feet, nose, udder.	Contact.	Rat, g. pig, mouse, monkey.	+	Mouse, g. pig embryo.	70-100[mf].	2 antigenic types.
88 Trachoma	Chlamydia trachomatis.	Man.	Conjunctiva, conjunctival exudate.	Contact, conjunctival exudate.	Ape, (man).	+		250[dm].	
89 Vaccinia		(Cutaneous lesions in man, rabbit, cattle).			Man, cattle, monkey, rabbit, mouse.	3 (and turtle).	Rabbit, g. pig, chick adult, embryo.	236-252[mf].	Antig. related to smallpox, agglut. RBC.
90 Vesicular exanthema, swine.	Hostis exanthematis.	Swine.	Lesions of nose, lip, mouth, feet, udder.	Contact, ingestion.	Horse, dog, hamster.		Swine embryo.	Passes N Berkefeld.	Several antigenic types.
91 Wart, human (verruca)	Molluscum verrucae.	Man.	Cutaneous lesions.	(Contact).	(Man).			Passes N Berkefeld.	
92 West Nile	Erro nili.	Man, pigeon.	Blood.	(Mosquito).	Mouse, g. pig, monkey, hamster, (man).	+	Mouse, chick embryo.	20-30[mf].	Antig. related to St. Louis, agglut. RBC.
93 Yellow fever	Reedella evagatus.	Man, monkey, galago.	Blood, liver, CNS, spleen, l.n.	Mosquito (Aedes, possibly others).	Mouse, monkey, hedgehog.	+	Chick, mouse embryo.	12-19[cl].	
94 Zika	Rocaea zika.	Man, monkey.	Blood.	(Isolated from Aedes mosquito).	Mouse.	+		18-26[mf].	

/6/ Raw. /9/ Also dog, fox, hedgehog (N. African). /10/ Also ascites tumor cells (man).

423. SELECTED RICKETTSIALES PARASITES: MAN AND DOMESTIC ANIMALS

	Organism	Host ¹	Disease	Method of Transmission
1	Anaplasma centrale	Cattle.	Benign anaplasmosis.	Tick to host.
2	A. marginale	Cattle.	Malignant anaplasmosis.	Tick to host.
3	A. ovis	Sheep, goats.	Ovine anaplasmosis.	Tick to host.
4	Bartonella bacilliformis	Man.	Oroya fever.	Sand fly to man.
5	Chlamydia trachomae	Man, ape, monkey.	Trachoma.	Contact.
6	C. oculogenitale	Man.	Inclusion blennorrhoea, inclusion conjunctivitis, neonatal conjunctivitis.	Contact. Contaminated swimming pools.
7	Coleiotes conjunctivae	Cattle, goat, sheep.	Ophthalmia.	
8	C. conjunctivae gallii	Birds.	Conjunctivitis, keratitis.	
9	Cowdria ruminantium	Goat, sheep, cattle.	"Heartwater."	Tick feces. Tick to host.
10	Coxiella burnetii	Man, cattle, sheep, goat.	Q fever.	Tick feces. Host to tick to host. Contact domestic animals. Inhalation infected dust. Contaminated milk.
11	Ehrlichia canis	Dog.	Canine rickettsiosis.	Tick to host.
12	E. bovis	Cattle.	Bovine rickettsiosis.	Tick to host.
13	E. ovina	Sheep.	Ovine rickettsiosis.	Presumed tick to host.
14	Eperythrozoon spp	Cattle, mouse, sheep, swine.	Eperythrozoonosis, anemia (parasite of erythrocyte).	Mouse louse to louse. Other arthropods suspected.
15	Grahamella talpae	Mole.	Grahamellosis, anemia (parasite of erythrocyte).	
16	Haemobartonella spp	Animals.	Haemobartonellosis, anemia (parasite of erythrocyte).	Flea to host.
17	Miyagawanella bronchopneumoniae	Mouse.	Mouse pneumonitis.	Contact.
18	M. felis	Cat.	Feline pneumonitis.	Contact.
19	M. lymphogranulomatosis	Man.	Lymphogranuloma venereum, lymphogranuloma inguinale.	Venereal contact.
20	M. ornithosis	Man, non-psittacine birds.	Ornithosis.	Similar to psittacosis (see below).
21	M. psittacii	Man, psittacine birds.	Psittacosis.	Inhalation infected dust. Bird to man, man to man.
22	Neorickettsia helminthoeca	Dog, fox, coyote.	"Salmon poisoning disease."	Intestinal parasitic fluke to man.
23	Rickettsia akari	Man.	Rickettsial pox.	Mite to man.
24	R. conorii	Man; dog as reservoir host.	Boutonneuse, Marseilles, Mediterranean fever.	Tick to man.
25	R. prowazekii	Man.	Epidemic typhus ("classic, Old World").	Louse feces. Man to louse to man.
26	R. quintana	Man.	Trench fever.	Body louse to man.
27	R. rickettsii	Man, rabbit, squirrel.	Rocky Mountain spotted fever.	Tick to man.
28	R. siberica	Man, rodents.	Siberian tick typhus.	Tick to host.
29	R. tsutsugamushi	Man, monkey, rodents.	Tsutsugamushi fever, scrub typhus.	Mite to man.
30	R. typhi	Man, rodents.	Murine or endemic typhus	Flea feces. Rat to flea to man.
31	Rickettsia spp	Domestic ruminants and fowl.	Conjunctivitis.	Uncertain.

/1/ Animals listed in order of decreasing susceptibility.

424. SELECTED BACTERIAL PARASITES: MAN AND DOMESTIC ANIMALS

	Bacterial Organism	Host ¹	Disease	Method of Transmission
1	Actinobacillus lignieresii	Cattle, swine.	Actinobacillosis, "wooden tongue."	(Not definitely known.)
2	Actinomyces bovis	Cattle, swine, horse, man.	Actinomycosis, "lumpy jaw."	Buccal cavity. (Not definitely known.)
3	Bacillus anthracis	Man.	Anthrax.	Soil-borne. Contact, infected animal by-products, carcasses.
4		Cattle, sheep, horse, mule, swine.	Anthrax, "splenic fever," "charbon," "milzbrand."	Soil-borne. Infected feed, water, carcasses.
5	Borrelia anserina	Fowl.	Spirochetosis.	Arthropod vector. Feces-borne.
6	B. recurrentis	Man.	European relapsing fever.	Arthropod vector.
7	B. theileri	Cattle.	Spirochetosis.	Arthropod vector.
8	B. vincentii	Man.	Associated with Fusobacterium plauti-vincenti in Vincent's angina.	Buccal cavity. (Not definitely known.)
9	Brucella abortus	Cattle, man.	Brucellosis, undulant fever.	Ingestion infected milk. Contact.
10	B. melitensis	Goat, sheep, man.	Brucellosis, undulant fever.	Ingestion infected milk. Contact.
11	B. suis	Swine, man.	Brucellosis, undulant fever.	Contact.
12	Clostridium botulinum	Man, chicken, duck, horse, mule, cattle.	Botulism, food intoxication, limber-neck of fowl.	Ingestion of toxin in food.
13	C. fescer	Cattle.	Black leg, symptomatic anthrax.	Soil-borne. Wound infection.
14	C. hemolyticum	Cattle, sheep.	Icterohemoglobinuria.	Soil-borne. Contaminated feed, water.
15	C. novyi	Sheep.	Infectious necrotic hepatitis.	Soil-borne. Associated with liver fluke infection.
16	C. perfringens	Man.	Gas gangrene.	} Soil-borne. Wound infection.
17		Sheep.	Lamb dysentery, infectious enterotoxemia.	
18	C. septicum	Horse, sheep, cattle.	Malignant edema.	Soil-borne. Wound infection.
19	C. tetani	Man, sheep, cattle, goat, swine, horse.	Tetanus, lockjaw.	Soil-borne. Wound infection.
20	Corynebacterium diphtheriae	Man.	Diphtheria.	Carrier contact.
21	C. equi	Horse.	Pneumonia of foal.	Possible in utero.
22		Swine.	Submaxillary gland infection.	Contaminated soil, feed.
23	C. pseudotuberculosis	Sheep, goat.	Gaseous lymphadenitis.	Contaminated feed, water.
24		Horse.	Ulcerative lymphangitis, pseudo-glanders.	Contact, wound infection.
25		Cattle.	Pseudotuberculosis.	
26	C. pyogenes	Cattle, swine, sheep, goat.	Mastitis, purulent infections, arthritis.	Inhabitant mucous membranes. Contact, wound infection.
27	C. renale	Cattle, swine.	Pyelonephritis.	Inhabitant mucous membranes. (Not definitely known.)

/1/ Animals are listed in order of decreasing susceptibility.

424. SELECTED BACTERIAL PARASITES: MAN AND DOMESTIC ANIMALS (Concluded)

	Bacterial Organism	Host ¹	Disease	Method of Transmission
28	<i>Diplococcus pneumoniae</i>	Man.	Lobar pneumonia, meningitis, endocarditis.	Carrier contact.
29	<i>Erysipelothrix rhusiopathiae</i>	Man.	Erysipeloid.	Wound infection, contact infected carcasses.
30		Swine, sheep, fowl.	Erysipeloid.	Feces-borne. Contaminated soil, feed, water.
31	<i>Escherichia coli</i>	Man, domestic animals.	Genito-urinary and intestinal infections.	Feces-borne. Normal flora of intestinal tract.
32	<i>Fusobacterium plauti-vincenti</i>	Man.	Associated with ulcerative stomatitis, Vincent's angina.	Buccal cavity. (Not definitely known.)
33	<i>Hemophilus ducreyi</i>	Man.	Soft chancre, chancroid.	Direct genital contact.
34	<i>H. gallinarum</i>	Chicken.	Infectious coryza.	Contact.
35	<i>H. hemoglobinophilus</i>	Dog.	Prepuccial infection.	Direct sexual contact.
36	<i>H. influenzae</i>	Man.	Meningitis, obstructive respiratory infections.	Flora of respiratory tract. Droplet infection.
37	<i>H. pertussis</i>	Man.	Whooping cough.	Flora of respiratory tract. Droplet infection.
38	<i>H. suis</i>	Swine.	Associated with viral influenza.	Contact.
39	<i>Klebsiella pneumoniae</i>	Man, horse, cattle.	Respiratory infection; mastitis (cattle).	Flora of respiratory tract. Droplet infection.
40	<i>Leptospira canicola</i>	Dog, man, swine, cattle.	Leptospirosis, Stuttgart's disease (dog).	Contact. Contamination of water by infected urine.
41	<i>L. icterohemorrhagiae</i>	Man, dog, swine, cattle, rodent.	Leptospirosis, Weil's disease.	Direct contact. Contamination of water by infected urine.
42	<i>L. pomona</i>	Cattle, swine, man.	Leptospirosis, swineherd's disease.	Direct contact. Contamination of water by infected urine.
43	<i>Listeria monocytogenes</i>	Man, domestic animals, fowl.	Listeriosis, meningoencephalitis.	(Not definitely known.)
44	<i>Malleomyces mallei</i>	Horse, man.	Glanders.	Contact. Contaminated feed, water.
45	<i>Micrococcus pyogenes</i>	Man, animals.	Abscesses, suppurative processes, food poisoning, septicemia.	Wound infection, ingestion contaminated food.
46	<i>Moraxella bovis</i>	Cattle.	Infectious keratitis.	Flora of skin and mucous membranes.
47	<i>M. lacunata</i>	Man.	Conjunctivitis.	Contact.
48	<i>Mycobacterium avium</i>	Fowl, swine.	Tuberculosis.	(Not definitely known.)
49	<i>M. leprae</i>	Man.	Hansen's disease, leprosy.	Contact. Feces-borne. Contaminated feed, water.
50	<i>M. paratuberculosis</i>	Cattle, sheep.	John's disease.	Contact. Feces-borne. Contaminated feed, water.
51	<i>M. tuberculosis var. bovis</i>	Cattle, man, swine.	Tuberculosis.	Contact. Feces-borne. Contaminated feed, water.
52	<i>M. tuberculosis var. hominis</i>	Man.	Tuberculosis.	Milk-borne.
53	<i>Neisseria catarrhalis</i>	Man.	Catarrhal inflammations.	Contact. Via respiratory or alimentary tract.
54	<i>N. gonorrhoeae</i>	Man.	Gonorrhea.	Flora of respiratory tract.
55	<i>N. meningitidis</i>	Man.	Epidemic cerebrospinal meningitis.	Direct sexual contact.
56	<i>Pasteurella multocida</i>	Domestic animals, fowl, man.	Hemorrhagic septicemia, bronchiectasis, conjunctivitis.	Infection from respiratory tract of carrier.
57	<i>P. pestis</i>	Man, rodent.	Bubonic and pneumonic plague.	Contact. Contaminated feed, water. Bites.
58	<i>P. tularensis</i>	Man, rodent.	Tularemia.	Flea bite from infected rat. Droplet infection.
59	<i>Proteus vulgaris</i>	Man.	Genito-urinary and intestinal (?) infection.	Contact contaminated carcasses. Insect vector.
60	<i>Pseudomonas aeruginosa</i>	Man, animals.	Suppurative processes, septicemia, meningitis, genito-urinary infections.	Feces-borne.
61	<i>Salmonella enteritidis</i>	Man, rodents.	Food poisoning, gastroenteritis.	Contaminated water, soil, feces, wound infection.
62	<i>S. gallinarum</i>	Fowl.	Fowl typhoid.	Feces-borne.
63	<i>S. hirschfeldii</i>	Man.	Paratyphoid fever.	Feces-borne. Ovarian transmission.
64	<i>S. paratyphi A</i>	Man.	Paratyphoid fever.	Feces-borne.
65	<i>S. paratyphi B</i>	Man.	Paratyphoid fever.	Feces-borne.
66	<i>S. pullorum</i>	Fowl.	Pullorum disease, bacillary white diarrhea.	Feces-borne. Ovarian transmission.
67	<i>S. typhimurium</i> ²	Man, rodents.	Food poisoning, gastroenteritis.	Feces-borne.
68	<i>S. typhosa</i>	Man.	Typhoid fever.	Feces-borne.
69	<i>Shigella dysenteriae</i>	Man.	Dysentery.	Feces-borne. Contaminated food, water.
70	<i>S. equuli</i>	Horse.	Joint infection, nephritis.	Contact. Fly-borne.
71	<i>Spherophorus necrophorus</i>	Man (?).	Associated with ulcerative colitis(?).	Possible in utero.
72		Horse.	Gangrenous dermatitis, "scratches."	Feces-borne. Associated with unsanitary conditions.
73		Cattle	Calf diphtheria.	
74		Sheep, goat	Lip-and-leg ulceration, ulcerative stomatitis, food rot.	
75		Swine.	Ulcerative stomatitis, enteritis.	
76	<i>Spirillum minus</i>	Man, rodents.	Rat-bite fever.	Rat bite.
77	<i>Streptococcus agalactiae</i>	Cattle.	Mastitis.	Contaminated milking equipment.
78	<i>S. dysgalactiae</i>	Cattle.	Mastitis.	Contaminated milking equipment.
79	<i>S. equi</i>	Horse.	Strangles.	Contact. Contaminated water, feed.
80	<i>S. pyogenes</i>	Man.	Scarlet fever, septic sore throat.	Direct personal contact, contaminated milk.
81	<i>S. uberis</i>	Cattle.	Mastitis.	Contaminated milking equipment.
82	<i>Treponema pallidum</i>	Man.	Syphilis.	Direct sexual contact.
83	<i>Vibrio comma</i>	Man.	Cholera.	Feces-borne from carrier. Contaminated food, water.
84	<i>V. fetus</i>	Cattle, sheep.	Vibriotic abortion, sterility.	Direct sexual contact.
85	<i>V. jejuni</i>	Cattle.	Dysentery.	Feces-borne. Contaminated feed and water.

/1/ Animals are listed in order of decreasing susceptibility. /2/ All warm-blooded animals.

425. SELECTED BACTERIAL PARASITES: PLANTS

Host Plant and Pathogen		Disease	Host Plant and Pathogen		Disease
1	Amaranth (<i>Amaranthus viridis</i>) <i>Xanthomonas amaranthicola</i>	Leaf spot.	57	Cherry, sweet (<i>Prunus avium</i>) <i>Pseudomonas syringae</i>	Gummosis and blight.
2	Apple (<i>Pyrus malus</i>) <i>Erwinia amylovora</i>	Fire blight.	58	Chicory, Witloof (<i>Cichorium intybus</i>) <i>Pseudomonas marginalis</i>	Rot.
3	<i>Pseudomonas papulans</i>	Blister spot.	59	<i>Chrysanthemum (Chrysanthemum morifolium)</i> <i>Erwinia chrysanthemi</i>	Bacterial blight.
4	<i>P. syringae</i>	Twig blight.	60	Chestnut (<i>Castanea spp</i>) <i>Pseudomonas castaneae</i>	Bacterial blight.
5	<i>P. melophthora</i>	Brown rot of fruit.	61	Citrus (<i>Citrus spp</i>) <i>Erwinia citrimaculans</i>	Fruit spot.
6	Alfalfa (<i>Medicago sativa</i>) <i>Corynebacterium insidiosum</i>	Wilt and root rot.	62	<i>Pseudomonas syringae</i>	Blast and black pit.
7	<i>Pseudomonas medicaginis</i>	Stem blight.	63	<i>Xanthomonas bilvae</i>	Shot hole and fruit canker.
8	Ash (<i>Fraxinus spp</i>) <i>Pseudomonas savastanoi</i> var. <i>fraxini</i>	Canker.	64	<i>X. citri</i>	Canker.
9	Banana (<i>Musa paradisi</i>) <i>Pseudomonas celebensis</i>	Blood disease.	65	Clover (<i>Trifolium spp</i>) <i>Pseudomonas radiciperda</i>	Root rot.
10	<i>P. solanacearum</i>	Brown rot.	66	<i>P. stizolobii</i>	Leaf spot.
11	<i>P. maublancii</i>	Bud rot and stunt.	67	<i>P. syringae</i>	Leaf spot.
12	Barley (<i>Hordeum vulgare</i>) <i>Pseudomonas coronafaciens</i>	Leaf spot.	68	Cocklebur (<i>Xanthium sp</i>) <i>Xanthomonas badrii</i>	Blight.
13	<i>P. striafaciens</i>	Stripe.	69	Corn (<i>Zea mays</i>) <i>Bacterium stewartii</i>	Wilt.
14	<i>Xanthomonas translucens</i> (f. sp)	Blight.	70	<i>Erwinia dissolvens</i>	Stock rot.
15	Barberry (<i>Berberis spp</i>) <i>Pseudomonas berberidis</i>	Leaf spot.	71	<i>Pseudomonas desaiiana</i>	Stinking rot.
16	Bean (<i>Phaseolus vulgaris</i>) <i>Corynebacterium flaccumfaciens</i>	Wilt.	72	<i>P. lapsa</i>	Leaf and stock rot.
17	<i>Pseudomonas phaseolicola</i>	Halo blight.	73	Cosmos (<i>Cosmos spp</i>) <i>Erwinia cosmovora</i>	Fire blight.
18	<i>P. stizolobii</i>	Leaf spot.	74	Cotton (<i>Gossypium spp</i>) <i>Xanthomonas malvacearum</i>	Angular leaf spot.
19	<i>P. syringae</i>	Lilac blight.	75	Cowpea (<i>Vigna sinensis</i>) <i>Pseudomonas syringae</i>	Bacterial leaf spot.
20	<i>P. viridiflava</i>	Leaf spot and blight.	76	<i>Xanthomonas vignicola</i>	Canker.
21	<i>Xanthomonas phaseoli</i>	Common blight.	77	Crucifers: cabbage, cauliflower, turnips, radish <i>Xanthomonas campestris</i>	Black rot.
22	<i>X. phaseoli</i> var. <i>fuscans</i>	Fuscos blight.	78	<i>X. vesicatoria</i> var. <i>raphani</i>	Blight.
23	Beet, sugar (<i>Beta vulgaris</i>) <i>Pseudomonas weringae</i>	Ring rot.	79	Cucumber (<i>Cucumis sativus</i>) <i>Pseudomonas lachrymans</i>	Angular leaf spot.
24	<i>Xanthomonas beticola</i>	Bacterial pocket.	80	Cucurbits: cucumber, squash, cantalopes <i>Erwinia tracheiphila</i>	Wilt.
25	Bottle pepper (<i>Piper betle</i>) <i>Pseudomonas betlis</i>	Leaf blight.	81	<i>Xanthomonas cucurbitae</i>	Leaf spot.
26	<i>Xanthomonas betticola</i>	Blight.	82	Cumin (<i>Cuminum spp</i>) <i>Pseudomonas cumini</i>	Blight.
27	Bindweed (<i>Polygonum convolvulus</i>) <i>Pseudomonas polygoni</i>	Leaf spot.	83	Curran (<i>Ribes aureum</i>) <i>Pseudomonas ribicola</i>	Leaf spot.
28	<i>Xanthomonas uppalii</i>	Wilt.	84	Dandelion, Russian (<i>Taraxacum kok-saghyz</i>) <i>Xanthomonas taraxaci</i>	Leaf blight.
29	Bowlesia (<i>Bowlesia septentrionalis</i>) <i>Pseudomonas bowlesiae</i>	Blight.	85	Delphinium (<i>Delphinium spp</i>) <i>Pseudomonas delphinii</i>	Black spot.
30	Broom grass (<i>Bromus spp</i>) <i>Pseudomonas coronafaciens</i>	Leaf spot.	86	Dianthus, Carnations, pinks (<i>Dianthus spp</i>) <i>Pseudomonas caryophylli</i>	Root rot and wilt.
31	var. <i>stropurpurea</i> <i>Xanthomonas translucens</i> (f. sp)	Blight.	87	<i>P. woodsii</i>	Leaf spot.
32	Begonia, tuberous (<i>Begonia spp</i> and hybrids) <i>Xanthomonas begoniae</i>	Leaf spot.	88	Dieffenbachia (<i>Dieffenbachia picta</i>) <i>Xanthomonas diffenbachiae</i>	Leaf spot.
33	Broad bean (<i>Vicia faba</i>) <i>Pseudomonas fabae</i>	Blight.	89	<i>Dysoxylum sectabile</i> <i>Pseudomonas dysoxyl</i>	Leaf spot.
34	<i>P. viciae</i>	Leaf and stem spot.	90	Elder (<i>Sambucus edulis</i>) <i>Xanthomonas sambuci</i>	Blight.
35	Burdock (<i>Arctium lappa</i>) <i>Xanthomonas nigromaculans</i>	Black spot.	91	Elm (<i>Ulmus spp</i>) <i>Erwinia nimipressuralis</i>	Wetwood.
36	Cabbage (<i>Brassica oleraceae</i> var. <i>capitata</i>) <i>Pseudomonas cichorii</i>	Zonate spot.	92	<i>Pseudomonas lignicola</i>	Black streak of wood.
37	<i>Xanthomonas campestris</i>	Black rot.	93	Fern, bird's nest (<i>Asplenium nidus</i>) <i>Pseudomonas asplenii</i>	Leaf blight.
38	Cactus (<i>Opuntia spp</i>) <i>Erwinia sp</i>	Soft rot.	94	Filbert (<i>Corylina spp</i>) <i>Pseudomonas columnae</i>	Leaf spot.
39	Cactus, giant (<i>Carnegieia gigantea</i>) <i>Erwinia carnegieana</i>	Rot or decay.	95	<i>Xanthomonas corylina</i>	Blight.
40	Calendula (<i>Calendula officinalis</i>) <i>Pseudomonas calendulae</i>	Leaf and stem spot.	96	Fir, Douglas (<i>Pseudotsuga taxifolia</i>) <i>Bacterium pseudotsugae</i>	Gall.
41	Canna (<i>Canna indica</i>) <i>Xanthomonas cannae</i>	Blight.	97	Flax, New Zealand (<i>Phormium tenax</i>) <i>Xanthomonas phormicola</i>	Leaf stripe.
42	Carpet grass (<i>Axonopus scoparius</i>) <i>Xanthomonas axonoperis</i>	Blight.	98	Fruit trees <i>Agrobacterium rhizogenes</i>	Hairy root.
43	Carrot (<i>Daucus carota</i> var. <i>sativa</i>) <i>Erwinia carotovora</i>	Soft rot.	99	<i>A. tumefaciens</i>	Crown gall.
44	<i>Xanthomonas carotae</i>	Leaf blight.	100	Geranium (<i>Geranium spp</i>) <i>Xanthomonas geranii</i>	Leaf spot.
45	Cassava (<i>Manihot spp</i>) <i>Erwinia cassavae</i>	Blight.	101	<i>X. pelargonii</i>	Leaf spot.
46	<i>Xanthomonas cassavae</i>	Leaf spot.	102	Gardenia (<i>Gardenia jasminoides</i>) <i>Pseudomonas gardinae</i>	Leaf spot.
47	<i>X. manihotis</i>	Wilt and gummosis.	103	<i>Xanthomonas maculifolium-gardeniae</i>	Leaf spot.
48	Castor bean (<i>Ricinus communis</i>) <i>Xanthomonas ricinicola</i>	Leaf spot.	104	Ginseng (<i>Panax quinquefolium</i>) <i>Pseudomonas panacis</i>	Root and stem rot.
49	Cauliflower (<i>Brassica oleraceae</i> var. <i>botrytis</i>) <i>Pseudomonas maculicola</i>	Peppery spot.	105	Gladiolus (<i>Gladiolus spp</i>) <i>Pseudomonas marginata</i>	Corm scab and leaf blight.
50	Celery (<i>Apium graveolens</i>) <i>Pseudomonas apii</i>	Leaf spot.	106	<i>P. gladioli</i>	Rot.
51	Cereals and grasses <i>Corynebacterium agropyri</i>	Yellow gum disease.	107	<i>Xanthomonas gummosudans</i>	Blight.
52	<i>C. rathayi</i>	Yellow gum disease.	108	Glorybower (<i>Clerodendron phlomoides</i>) <i>Xanthomonas clerodendroni</i>	Leaf spot.
53	<i>C. tritici</i>	Yellow gum disease.			
54	<i>Pseudomonas albobiprecipitans</i>	Streak.			
55	<i>P. coronafaciens</i>	Streak.			
56	<i>Xanthomonas translucens</i> various f. sp	Blight.			

425. SELECTED BACTERIAL PARASITES: PLANTS (Continued)

Host Plant and Pathogen		Disease	Host Plant and Pathogen		Disease
109	Grape (<i>Vitis vinifera</i>)		160	Pangara tree (<i>Erythrina indica</i>)	
110	<i>Erwinia vitivora</i>	Dead arm.		<i>Xanthomonas erythrinae</i>	Leaf spot.
	<i>Pseudomonas tumefaciens</i>	Black knot.	161	Passion-flower (<i>Passiflora edulis</i>)	
111	Guayule (<i>Parthenium argentatum</i>)			<i>Pseudomonas passiflorae</i>	Grease spot.
	<i>Erwinia carotovora</i> f. sp. <i>parthenii</i>	Root and stem rot.	162	Pea (<i>Pisum sativum</i>)	
	<i>Gypsophila</i> (<i>Gypsophila</i> sp.)			<i>Pseudomonas pisi</i>	Blight.
112	<i>Agrobacterium gypsophillae</i>	Gall.	163	Pea, pigeon (<i>Cajanus cajan</i>)	
	<i>Henna</i> (<i>Lawsonia inermis</i>)			<i>Xanthomonas cajani</i>	Blight.
113	<i>Xanthomonas lawsoniae</i>	Leaf spot.	164	Peach (<i>Prunus persica</i>)	
	Heron'sbill (<i>Erodium texanum</i>)			<i>Xanthomonas pruni</i>	Spot of leaf and fruit.
114	<i>Pseudomonas erodii</i>	Leaf spot.	165	Pear (<i>Pyrus communis</i>)	
	Horseradish (<i>Armoracia lapathifolia</i>)			<i>Erwinia amylovora</i>	Fire blight.
115	<i>Xanthomonas campestris</i> var. <i>armoraciae</i>	Leaf spot.	166	<i>Pseudomonas syringae</i>	Twig and blossom blight.
	Hyacinth (<i>Hyacinthus orientalis</i>)		167	<i>P. barkeri</i>	Blossom blight.
116	<i>Xanthomonas hyacinthi</i>	Yellow disease.	168	<i>P. nectarophila</i>	Blossom blight.
117	<i>Erwinia</i> spp.	Soft rot.	169	Pelargonium (<i>Pelargonium</i> spp.)	
	Iris (<i>Iris</i> spp.)			<i>Pseudomonas erodii</i>	Leaf spot.
118	<i>Bacterium tardicrescens</i>	Leaf blight.	170	<i>Xanthomonas pelargonii</i>	Leaf spot and stalk rot.
119	<i>Pseudomonas cichorii</i>	Leaf blight.	171	Pineapple (<i>Ananas comosus</i>)	
120	<i>P. iridicola</i>	Leaf blight.		<i>Erwinia ananas</i>	Brown rot.
	Ivy (<i>Hedera helix</i>)		172	<i>Pseudomonas ananas</i>	Black rot.
121	<i>Xanthomonas hederiae</i>	Leaf spot.	173	Plantain (<i>Plantago lanceolata</i>)	
	Ivy, Japanese (<i>Cissus japonica</i>)			<i>Xanthomonas plantaginis</i>	Leaf spot.
122	<i>Pseudomonas cissicola</i>	Black spot.	174	Plum (<i>Prunus</i> spp.)	
	Jimson weed (<i>Datura</i> spp.)			<i>Pseudomonas mors-prunorum</i>	Canker and stunt.
123	<i>Xanthomonas hermiana</i>	Leaf spot.	175	<i>P. syringae</i>	Blight and gummosis.
	Jute (<i>Corchorus capsularis</i>)		176	<i>Xanthomonas pruni</i>	Fruit and leaf spot.
124	<i>Xanthomonas nakatae</i>	Leaf spot.	177	Poinsettia (<i>Euphorbia pulcherrima</i>)	
	Larkspur (<i>Delphinium</i> spp.)			<i>Corynebacterium poinsettiae</i>	Leaf and stem streak.
125	<i>Erwinia atroseptica</i>	Black leg.	178	<i>Xanthomonas poinsettiae</i>	Leaf spot.
	Laurel, California (<i>Umbellularia californica</i>)		179	Poplar (<i>Populus</i> spp.)	
126	<i>Pseudomonas lauracearum</i>	Leaf spot.		<i>Corynebacterium humiferum</i>	Wet wood.
	Lespedeza (<i>Lespedeza</i> spp.)		180	<i>Pseudomonas rimaefaciens</i>	Canker.
127	<i>Xanthomonas lespedezae</i>	Wilt.	181	Poppy (<i>Papaver</i> spp.)	
	Lettuce (<i>Lactuca sativa</i>)			<i>Pseudomonas papaveris</i>	Black streak.
128	<i>Pseudomonas cichorii</i>	Head rot.	182	<i>Xanthomonas papavericola</i>	Black spot.
129	<i>P. marginalis</i>	Marginal blight and rot.	183	Potato (<i>Solanum tuberosum</i>)	
130	<i>P. viridilivida</i>	Leaf spot and blight.		<i>Bacillus</i> spp.	Storage rots.
131	<i>Xanthomonas vitians</i>	Wilt and rot.	184	<i>Corynebacterium sepedonicum</i>	Ring rot.
	Lilac (<i>Syringa vulgaris</i>)		185	<i>Erwinia atroseptica</i>	Black leg.
132	<i>Pseudomonas syringae</i>	Blight.	186	<i>Erwinia</i> spp.	Soft rot.
	Loquat (<i>Eriobotrya japonica</i>)		187	<i>Streptomyces scabies</i>	Scab.
133	<i>Pseudomonas erobotryae</i>	Bud rot.	188	Primrose (<i>Primula</i> spp.)	
	Lovage (<i>Levisticum officinale</i>)			<i>Pseudomonas primulae</i>	Leaf spot.
134	<i>Pseudomonas levistica</i>	Leaf blight.	189	Privet (<i>Ligustrum japonicum</i>)	
	Lupine (<i>Lupinus</i> spp.)			<i>Pseudomonas ligustri</i>	Leaf spot.
135	<i>Erwinia lupini</i>	Brown blight.	190	Solanaceae: eggplant, pepper, tomato, potato	
136	<i>Xanthomonas phaseoli</i>	Blight.		<i>Pseudomonas solanacearum</i>	Southern wilt or brown rot.
	Mango (<i>Mangifera indica</i>)		191	Rhubarb (<i>Rheum rhabonticum</i>)	
137	<i>Bacillus subtilis</i>	Soft rot.		<i>Erwinia rhabontici</i>	Crown rot.
138	<i>Erwinia mangiferae</i>	Leaf, stem and fruit blight.	192	Rice (<i>Oryza sativa</i>)	
	<i>Pseudomonas mangiferae-indicae</i>	Leaf spot.	193	<i>Xanthomonas oryzae</i>	Leaf blotch.
	Maple (<i>Acer</i> spp.)			<i>X. kresek</i>	Kresek disease.
140	<i>Pseudomonas aceris</i>	Leaf spot.	194	Rose-mallow (<i>Hibiscus</i> spp.)	
141	<i>Xanthomonas acernea</i>	Leaf blight.		<i>Pseudomonas syringae</i>	Blight.
	Marigold, African (<i>Tagetes erecta</i>)		195	Rubus	
142	<i>Pseudomonas tagetes</i>	Leaf spot.		<i>Agrobacterium rubi</i>	Gall.
	Morning glory (<i>Ipomoea musicata</i>)		196	<i>Erwinia amylovora</i> f. sp. <i>rubi</i>	Blight.
143	<i>Xanthomonas uppalli</i>	Blight.	197	Senna (<i>Cassia tora</i>)	
	Mulberry (<i>Morus</i> spp.)			<i>Xanthomonas cassiae</i>	Blight.
144	<i>Pseudomonas mori</i>	Blight.	198	Sesbania (<i>Sesbania</i> sp.)	
	Millet, foxtail (<i>Setaria italica</i>)			<i>Xanthomonas sesbaniae</i>	Leaf spot.
145	<i>Pseudomonas setariae</i>	Brown stripe.	199	Sesame (<i>Sesamum orientale</i>)	
	Millet, broom corn (<i>Panicum miliaceum</i>)			<i>Pseudomonas sesami</i>	Blight.
146	<i>Pseudomonas panici-miliacei</i>	Leaf stripe.	200	Snapdragon (<i>Antirrhinum majus</i>)	
147	<i>Xanthomonas panici</i>	Streak.		<i>Xanthomonas antirrhini</i>	Leaf spot.
	Mushroom (<i>Agaricus campestris</i>)		201	Sorghum (<i>Sorghum</i> spp.)	
148	<i>Pseudomonas tolaasi</i>	Spot.		<i>Pseudomonas andropogoni</i>	Leaf blotch and streak.
	Oat (<i>Avena sativa</i>)		202	<i>Xanthomonas holcicola</i>	Leaf spot.
149	<i>Pseudomonas coronafaciens</i>	Halo blight.	203	Soybean (<i>Glycine max</i>)	
150	<i>P. coronafaciens</i> var. <i>atropurpurea</i>	Purple spot.		<i>Pseudomonas glycinea</i>	Leaf spot.
151	<i>Xanthomonas translucens</i> (f. sp.)	Blight.	204	<i>P. tabaci</i>	Wildfire.
	Oleander (<i>Nerium oleander</i>)		205	<i>Xanthomonas phaseoli</i> var. <i>sojensis</i>	Pustule.
152	<i>Pseudomonas tonelliana</i>	Gall.	206	Stock (<i>Matthiola incana</i>)	
	Olive (<i>Olea</i> spp.)			<i>Pseudomonas matthiolae</i>	Blight.
153	<i>Pseudomonas savastanoi</i>	Knott.	207	<i>P. syringae</i>	Blight.
	Onion (<i>Allium cepa</i>)		208	<i>Xanthomonas incanae</i>	Blight.
154	<i>Pseudomonas allii</i>	Scale rot.	209	Sugar cane (<i>Saccharum officinarum</i>)	
155	<i>P. cepacia</i>	Sour skin.		<i>Bacterium albilineans</i>	White streak and wilt.
156	<i>P. cichorii</i> and <i>P. marginalis</i>	Soft rot.	210	<i>Xanthomonas rubilineans</i>	Red streak.
157	<i>Xanthomonas striiformans</i>	Stripe.	211	<i>X. rubrisubalbicans</i>	Mottled stripe.
	Orchids		212	<i>X. vasculocum</i>	Gummosis.
158	<i>Pseudomonas cattleyae</i>	Leaf spot.	213	Sunflower (<i>Helianthus</i> spp.)	
	Palm, Washington (<i>Washingtonia filifera</i>)			<i>Pseudomonas helianthi</i>	Leaf spot.
159	<i>Pseudomonas washingtoniae</i>	Leaf blight.	214	Sweet coltsfoot (<i>Petasites japonica</i>)	
				<i>Pseudomonas petasites</i>	Black spot.

425. SELECTED BACTERIAL PARASITES: PLANTS (Concluded)

Host Plant and Pathogen		Disease	Host Plant and Pathogen		Disease
215	Tamarind (<i>Tamarindus indica</i>) <i>Xanthomonas tamarindi</i>	Leaf spot.	239	Velvet bean (<i>Stizolobium deeringianum</i>) <i>Pseudomonas stizolobii</i>	Leaf spot.
216	Sweetpea and numerous other plants <i>Corynebacterium fascians</i>	Fasciation.	240	<i>Xanthomonas stizolobicola</i>	Blight.
217	Teakwood (<i>Tectona grandis</i>) <i>Pseudomonas tectonae</i>	Seedling wilt.	241	Vetch, milk (<i>Astragalus</i> sp) <i>Pseudomonas astragali</i>	Black spot.
218	<i>Xanthomonas melhusii</i>	Leaf spot.	242	Viburnum (<i>Viburnum</i> spp) <i>Pseudomonas viburni</i>	Leaf spot.
219	Tick-trefoil (<i>Desmodium diffusum</i> , <i>D. gangeticum</i>) <i>Xanthomonas desmodii</i>	Blight.	243	Walnut (<i>Juglans</i> spp) <i>Xanthomonas juglandis</i>	Blight.
220	<i>X. desmodii-gangetica</i>	Blight.	244	Wheat (<i>Triticum aestivum</i>) <i>Pseudomonas atrofaciens</i>	Basal glume rot.
221	Tobacco (<i>Nicotiana</i> spp) <i>Erwinia ardioeae</i>	Hollow stalk and barn rot.	245	<i>Xanthomonas translucens</i> f. <i>sp undulosa</i>	Black chaff.
222	<i>Pseudomonas angulata</i>	Angular leaf spot.	246	Willow (<i>Salix</i> spp) <i>Erwinia salicis</i>	Blight.
223	<i>P. mellea</i>	Rust.	247	<i>Pseudomonas saliciperda</i>	Blight.
224	<i>P. polycolor</i>	Leaf spot and wet rot.	248	Winter cress (<i>Barbarea vulgaris</i>) <i>Xanthomonas barbareae</i>	Leaf blight.
225	<i>P. pseudozooglaeae</i>	Black rust.	249	Wisteria, Japanese (<i>Millettia floribunda</i>) <i>Erwinia millettiae</i>	Galls.
226	<i>P. solanacearum</i>	Granville disease.	250	Zinnia (<i>Zinnia elegans</i>) <i>Xanthomonas nigromaculans</i> f. <i>sp zinniae</i>	Angular leaf spot.
227	<i>P. tabaci</i>	Wildfire.	251	Numerous plants <i>Agrobacterium tumefaciens</i>	Crown gall.
228	<i>Xanthomonas heterocheae</i>	Rust.	252	<i>Corynebacterium fascians</i>	Fasciation.
229	Tomato (<i>Lycopersicon esculentum</i>) <i>Corynebacterium michiganense</i>	Canker and wilt.	253	<i>Erwinia amylovora</i>	Fire blight of Rosaceae.
230	<i>Pseudomonas tomato</i>	Bacterial speck.	254	<i>E. ardioeae</i>	Soft rot.
231	<i>Xanthomonas vesicatoria</i>	Pustule.	255	<i>E. atroseptica</i>	Soft rot.
232	<i>Trichodesma zeylanicum</i> <i>Xanthomonas trichodesmae</i>	Leaf spot.	256	<i>E. carotovora</i>	Soft rot.
233	Tung-oil tree (<i>Aleurites fordii</i>) <i>Pseudomonas aleuritidis</i>	Angular leaf spot.	257	<i>E. chrysanthemi</i>	Soft rot.
234	Unicorn-plant (<i>Martynia louisiana</i>) <i>Pseudomonas martyniae</i>	Blight.	258	<i>Pseudomonas solanacearum</i>	Brown rot.
235	Vegetables (fleshy), plants of tuberous and fleshy roots <i>Erwinia ardioeae</i>	Soft rots.	259	<i>P. syringae</i>	Blight.
236	<i>E. atroseptica</i>	Soft rots.			
237	<i>E. carotovora</i>	Soft rots.			
238	<i>E. chrysanthemi</i>	Soft rots.			

426. SELECTED FUNGAL PARASITES: FIELD, FRUIT, VEGETABLE CROPS

Host Plant and Pathogen		Disease	Host Plant and Pathogen		Disease
Field Crops: Cereals			Field Crops: Cereals (concluded)		
1	Barley (<i>Hordeum vulgare</i>) <i>Erysiphe graminis</i>	Powdery mildew.	36	Sorghum (<i>Sorghum</i> spp) <i>Ascochyta sorghina</i>	Rough spot.
2	<i>Gibberella zeae</i>	Fusarium blight, scab.	37	<i>Cercospora sorghina</i>	Gray leaf spot.
3	<i>Helminthosporium gramineum</i>	Stripe disease.	38	<i>Colletotrichum graminicola</i>	Anthrachnose.
4	<i>H. sativum</i>	Spot blotch, root rot, foot rot, kernel blight.	39	<i>Gloeocercospora sorghi</i>	Zonate leaf spot.
5	<i>Puccinia graminis</i> , <i>P. tritici</i>	Stern rust.	40	<i>Helminthosporium sorghicola</i>	Target spot.
6	<i>P. hordei</i>	Leaf rust.	41	<i>H. turcicum</i>	Leaf blight.
7	<i>Pyrenophora teres</i>	Net blotch.	42	<i>Macrophomina phaseolina</i>	Charcoal or stalk rot.
8	<i>Rhynchosporium secalis</i>	Scald.	43	<i>Periconia circinata</i>	Milo disease, root rot.
9	<i>Typhula itoana</i>	Snow mold.	44	<i>Ramulispora sorghi</i>	Sooty stripe.
10	<i>Ustilago hordei</i>	Covered smut.	45	<i>Sphacelotheca cruenta</i>	Loose kernel smut.
11	<i>U. nigra</i>	Black or semi-loose smut.	46	<i>S. sorghi</i>	Covered kernel smut.
12	<i>U. nuda</i>	Loose smut.	47	Wheat (<i>Triticum aestivum</i>) <i>Erysiphe graminis tritici</i>	Powdery mildew.
13	Corn (<i>Zea mays</i>) <i>Cochliobolus heterostrophus</i>	Southern leaf blight, seedling blight.	48	<i>Gibberella zeae</i>	Fusarium blight or scab.
14	<i>Diplodia zeae</i> , <i>D. macrospora</i>	Stalk rot, dry ear rot.	49	<i>Helminthosporium sativum</i>	Crown rot, root rot.
15	<i>Gibberella fujikuroi</i>	Pink ear rot, seedling blight.	50	<i>Leptosphaeria nodorum</i>	Glume blotch, node canker.
16	<i>G. zeae</i>	Stalk rot, red ear rot, seedling blight, root rot.	51	<i>Ophiobolus graminis</i>	Take-all.
17	<i>Helminthosporium carbonum</i>	Northern leaf spot, charred ear, seedling blight.	52	<i>Puccinia glumarum</i>	Stripe rust.
18	<i>H. turcicum</i>	Northern leaf blight, seedling blight.	53	<i>P. graminis tritici</i>	Stem rust.
19	<i>Physalospora zeae</i>	Gray ear rot.	54	<i>P. rubigo-vera tritici</i>	Leaf rust.
20	<i>Puccinia sorghi</i>	Rust.	55	<i>Septoria tritici</i>	Leaf blotch.
21	<i>Sclerospora graminicola</i>	Downy mildew.	56	<i>Tilletia brevifaciens</i>	Dwarf bunt.
22	<i>Ustilago maydis</i>	Smut.	57	<i>T. caries</i> , <i>T. foetida</i>	Bunt or stinking smut.
23	Oats (<i>Avena sativa</i>) <i>Leptosphaeria avenaria</i>	Black stem.	58	<i>Urocystis tritici</i>	Flag smut.
24	<i>Puccinia coronata avenae</i>	Crown rust.	59	<i>Ustilago tritici</i>	Loose smut.
25	<i>P. graminis avenae</i>	Stem rust.	Field Crops: Legumes		
26	<i>Ustilago avenae</i>	Loose smut.	60	Alfalfa (<i>Medicago sativa</i>) <i>Ascochyta medicaginis</i>	Spring black stem.
27	<i>U. kolleri</i>	Covered smut.	61	<i>Leptosphaeria pratensis</i>	Leaf spot, root rot, crown rot.
28	Rice (<i>Oryza sativa</i>) <i>Cercospora oryzae</i>	Cercospora spot.	62	<i>Peronospora trifoliorum</i>	Downy mildew.
29	<i>Cochliobolus miyabeanus</i>	Helminthosporium blight.	63	<i>Pseudopeziza medicaginis</i>	Common leaf spot.
30	Rye (<i>Secale cereale</i>) <i>Claviceps purpurea</i>	Ergot.	64	<i>P. jonesii</i>	Yellow leaf blotch.
31	<i>Erysiphe graminis</i>	Powdery mildew.	65	<i>Sclerotinia trifoliorum</i>	Crown rot, root rot.
32	<i>Gibberella zeae</i>	Fusarium blight, scab.	66	<i>Uromyces striatus medicaginis</i>	Rust.
33	<i>Puccinia graminis secalis</i>	Stem rust.	67	<i>Urophlyctis alfalfae</i>	Crown wart.
34	<i>P. rubigo-vera secalis</i>	Leaf rust.	68	Clover (<i>Trifolium</i> spp) <i>Colletotrichum trifolii</i>	Southern anthrachnose.
35	<i>Urocystis occulta</i>	Stem smut.	69	<i>Cynadothea trifolii</i>	Sooty blotch (red, white and alsike clover).
			70	<i>Erysiphe polygoni</i>	Powdery mildew (red clover).
			71	<i>Kabatella caulivora</i>	Northern anthrachnose (crimson and red clover).
			72	<i>Phoma trifolii</i>	Spring black stem (red clover).
			73	<i>Pseudopeziza trifolii</i>	Leaf spot.

426. SELECTED FUNGAL PARASITES: FIELD, FRUIT, VEGETABLE CROPS (Continued)

Host Plant and Pathogen		Disease	Host Plant and Pathogen		Disease
Field Crops: Legumes (concluded)			Fruit Crops (continued)		
74	Clover (<i>Trifolium</i> spp) (concluded)	Root rot, crown rot.	137	Avocado (<i>Persea americana</i>)	
75	<i>Sclerotinia trifoliorum</i>	Rust.		<i>Botryosphaeria ribis</i>	Branch canker, fruit rot.
	<i>Uromyces trifolii</i>			<i>chromogena</i>	Cercospora spot or blotch.
76	<i>Lespedeza</i> spp	Powdery mildew.	138	<i>Cercospora purpurea</i>	Anthrachnose or black spot.
	<i>Microsphaera diffusa</i>		139	<i>Colletotrichum gloeosporioides</i>	Stem-end rot.
	Soybean (<i>Glycine soja</i>)		140	<i>Diplodia theobromae</i>	Stem-end rot.
77	<i>Cephalosporium gregatum</i>	Brown stem rot.	141	<i>Phomopsis</i> sp	Phytophthora root rot.
78	<i>Cercospora soja</i>	Frog-eye leaf spot.	142	<i>Phytophthora cinnamomi</i>	Scab (fruit and foliage).
79	<i>Colletotrichum truncatum</i>	Anthrachnose.	143	<i>Sphaceloma perseae</i>	Verticillium wilt.
80	<i>Corynespora cassiicola</i>	Target spot.	144	<i>Verticillium albo-atrum</i>	
81	<i>Diaporthe phaseolorum batatis</i>	Stem canker.		Blackberry (<i>Rubus</i> spp)	
82	<i>D. phaseolorum sojae</i>	Pod and stem blight.	145	<i>Cercospora rubi</i>	Double blossom.
83	<i>Fusarium oxysporum</i>		146	<i>Elsinoë veneta</i>	Anthrachnose.
	<i>tracheiphilum</i>	Fusarium wilt.	147	<i>Kuehneola uredinis</i>	Yellow leaf and cane rust.
84	<i>Glomerella glycines</i>	Anthrachnose.	148	<i>Septoria rubi</i>	Leaf and cane spot.
85	<i>Macrophomina phaseoli</i>	Ashy stem blight.	149	<i>Verticillium albo-atrum</i>	Verticillium wilt.
86	<i>Pellicularia rolfsii</i>	Southern wilt.		Blueberry (<i>Vaccinium</i> spp)	
87	<i>Peronospora manshurica</i>	Downy mildew.	150	<i>Botrytis cinerea</i>	Blossom, fruit and twig blight.
88	<i>Phyllosticta sojaicola</i>	Leaf spot.	151	<i>Dothichiza caroliniana</i>	Leaf spot.
89	<i>Phymatotrichum omnivorum</i>	Texas root rot.	152	<i>Microsphaera alni vaccinii</i>	Powdery mildew.
90	<i>Sclerotinia sclerotiorum</i>	Stem rot.	153	<i>Monilinia vaccinii corymbosi</i>	Mummy berry.
91	<i>Septoria glycines</i>	Brown spot.	154	<i>Physalospora corticis</i>	Stem canker.
	Sweetclover (<i>Melilotus alba</i>)			Cherry (<i>Prunus</i> spp)	
92	<i>Ascochyta</i> spp	Leaf, stem, and pod blight.	155	<i>Botrytis cinerea</i>	Gray mold.
93	<i>Cercospora zebrina</i>	Leaf spot.	156	<i>Coccomyces hiemalis</i>	Leaf spot.
94	<i>Leptosphaeria pratensis</i>	Leaf spot, crown rot, root rot.	157	<i>Monilinia fruticola</i>	Brown rot, blossom blight.
95	<i>Mycosphaerella davisii</i>	Leaf spot.	158	<i>M. laxa</i>	European brown rot, blossom and twig blight.
96	<i>M. lethalis</i>	Black stem.		<i>Podosphaera oxycanthae</i>	Powdery mildew.
97	<i>Phytophthora cactorum</i>	Root rot.	159		
98	<i>Pseudopeziza melilotae</i>	Common leaf spot.		Citrus (<i>Citrus</i> spp)	
	Field Crops: Miscellaneous		160	<i>Clitocybe tabescens</i>	Root rot.
99	Cotton (<i>Gossypium</i> spp)		161	<i>Diaporthe citri</i>	Melanose, stem-end rot.
	<i>Fusarium oxysporum</i>		162	<i>Diplodia natalensis</i>	Twig and branch dieback, stem-end rot.
	<i>vasinfectum</i>	Fusarium wilt.		<i>Elsinoë fawcetti</i>	Scab.
100	<i>Glomerella gossypii</i>	Anthrachnose.	163	<i>Glomerella cingulata</i>	Withertip, anthracnose.
101	<i>Pellicularia filamentosa</i>	"Soreshin" seedling stem canker.	164	<i>Phytophthora citrophthora</i>	Foot rot, brown rot.
102	<i>Phymatotrichum omnivorum</i>	Root rot.		Cranberry (<i>Vaccinium</i> spp)	
103	<i>Puccinia stakmanii</i>	Rust.	166	<i>Acanthorhynchus vaccinii</i>	Blotch rot of berries.
104	<i>Verticillium albo-atrum</i>	Wilt.	167	<i>Diplodia vaccinii</i>	Twig blight.
	Flax (<i>Linum usitatissimum</i>)		168	<i>Glomerella cingulata vaccinii</i>	Bitter rot, leaf spot.
105	<i>Colletotrichum lini</i>	Anthrachnose.	169	<i>Guignardia vaccinii</i>	Early rot, scald, blast.
106	<i>Fusarium oxysporum lini</i>	Fusarium wilt.	170	<i>Sporonema oxycocci</i>	Leaf spot, berry rot.
107	<i>Melampsora lini</i>	Rust.		Fig (<i>Ficus carica</i>)	
108	<i>Mycosphaerella linorum</i>	Pasmo disease.	171	<i>Glomerella cingulata</i>	Anthrachnose.
	Peanut (<i>Arachis hypogaea</i>)		172	<i>Physopella fici</i>	Rust.
109	<i>Macrophomina phaseoli</i>	Seedling blight.	173	<i>Rhizoctonia microsclerotia</i>	Leaf blight, web blight.
110	<i>Mycosphaerella arachidicola</i>	Early leaf spot.		Grape (<i>Vitis</i> spp)	
111	<i>Pellicularia filamentosa</i>	Dry rot.	174	<i>Cryptosporella viticola</i>	Dead arm.
112	<i>P. rolfsii</i>	Southern blight.	175	<i>Elsinoë ampelina</i>	Anthrachnose.
	Sugar cane (<i>Saccharum officinarum</i>)		176	<i>Guignardia bidwellii</i>	Black rot.
113	<i>Helminthosporium sacchari</i>	Eyespot.	177	<i>Plasmopara viticola</i>	Downy mildew.
114	<i>Physalospora tucumanensis</i>	Red rot.	178	<i>Uncinula necator</i>	Powdery mildew.
	Peppermint, spearmint (<i>Mentha</i> spp)			Olive (<i>Olea europaea</i>)	
115	<i>Puccinia menthae</i>	Rust.	179	<i>Armillaria mellea</i>	Root rot.
116	<i>Verticillium albo-atrum</i>	Verticillium wilt.	180	<i>Asterina oleina</i>	Black leaf spot.
	Tobacco (<i>Nicotiana tabacum</i>)		181	<i>Cycloconium oleaginum</i>	Leaf spot.
117	<i>Cercospora nicotianae</i>	Frog-eye leaf spot.	182	<i>Gloeosporium olivarium</i>	Anthrachnose.
118	<i>Fusarium oxysporum</i> ¹	Fusarium wilt.	183	<i>Phymatotrichum omnivorum</i>	Root rot.
119	<i>Macrophomina phaseoli</i>	Charcoal rot.		Peach (<i>Prunus persica</i>)	
120	<i>Pellicularia filamentosa</i>	Stem canker.	184	<i>Armillaria mellea</i>	Root rot.
121	<i>Peronospora tabacina</i>	Blue mold.	185	<i>Clitocybe tabescens</i>	Root rot.
122	<i>Phytophthora parasitica</i> ¹	Black shank.	186	<i>Coryneum carpophilum</i>	Blight, shot-hole.
123	<i>Thielaviopsis basicola</i>	Black rot.	187	<i>Glomerella cingulata</i>	Ripe rot, twig blight.
	Fruit Crops		188	<i>Monilinia fruticola</i>	Brown rot, twig canker.
124	Apple (<i>Pyrus malus</i>)		189	<i>Taphrina deformans</i>	Leaf curl.
125	<i>Clitocybe tabescens</i>	Root rot.		Pear (<i>Pyrus communis</i>)	
126	<i>Corticium galactinum</i>	White root rot.	190	<i>Botrytis cinerea</i>	Gray mold.
127	<i>Gloeodes pomigena</i>	Sooty blotch.	191	<i>Clitocybe tabescens</i>	Root rot.
128	<i>Glomerella cingulata</i>	Bitter rot of fruit, stem canker.	192	<i>Neofabraea malicorticis</i>	Black spot canker.
	<i>Gymnosporangium juniperi virginianae</i>		193	<i>N. perennans</i>	Perennial canker.
129	<i>Phyllosticta solitaria</i>	Rust.	194	<i>Podosphaera leucotricha</i>	Powdery mildew.
130	<i>Podosphaera leucotricha</i>	Blotch, leaf spot, canker.	195	<i>Venturia pyrina</i>	Scab.
131	<i>Venturia inaequalis</i>	Powdery mildew.		Plum (<i>Prunus domestica</i>)	
132	<i>Xylaria mali</i>	Scab.	196	<i>Armillaria mellea</i>	Root rot.
	Apricot (<i>Prunus armeniaca</i>)		197	<i>Monilinia fruticola</i>	Brown rot, blossom blight.
133	<i>Armillaria mellea</i>	Black root rot.	198	<i>M. laxa</i>	European brown rot, blossom and twig blight.
134	<i>Coryneum carpophilum</i>	Root rot.		Raspberry (<i>Rubus</i> spp)	
135	<i>Monilinia fruticola</i>	Coryneum blight.	199	<i>Didymella applanata</i>	Spur blight.
136	<i>M. laxa</i>	Brown rot (ripe fruit)	200	<i>Elsinoë veneta</i>	Anthrachnose.
		Brown rot (green and ripe fruit), blossom and twig blight.	201	<i>Phragmidium rubi-idaei</i>	Rust.

/1/ Variety *nicotianae*.

426. SELECTED FUNGAL PARASITES: FIELD, FRUIT, VEGETABLE CROPS (Concluded)

Host Plant and Pathogen		Disease	Host Plant and Pathogen		Disease
Fruit Crops (concluded)			Vegetable Crops (concluded)		
202	Raspberry (<i>Rubus</i> spp) (concluded)		252	Crucifer (<i>Brassica</i> spp) ²	
	<i>Septoria rubi</i>	Leaf and cane spot.		<i>Alternaria brassicae</i>	Gray leaf spot.
203	Strawberry (<i>Fragaria chiloensis</i>)		253	<i>Fusarium oxysporum</i>	
	<i>Botrytis cinerea</i>	Gray mold rot.		<i>conglutinans</i>	Yellows.
204	<i>Dendrophoma obscurans</i>	Leaf blight, stem-end rot.	254	<i>Mycosphaerella brassicicola</i>	Ring spot.
205	<i>Diplocarpon earliana</i>	Leaf scorch.	255	<i>Peronospora parasitica</i>	Downy mildew.
206	<i>Mycosphaerella fragariae</i>	Leaf spot.	256	<i>Phoma lingam</i>	Blackleg.
207	<i>Phytophthora fragariae</i>	Red stele.	257	<i>Phytophthora megasperma</i>	Root rot of cabbage, cauliflower, and brussel sprouts.
Nut Crops					Clubroot.
208	Almond (<i>Prunus amygdalus</i>)		258	<i>Plasmodiophora brassicae</i>	
	<i>Armillaria mellea</i>	Root rot.		<i>Cucurbit</i> (<i>Cucurbita</i> spp) ³	
209	<i>Coryneum carpophilum</i>	Blight, shot-hole.	259	<i>Alternaria cucurbitina</i>	Leaf blight.
210	<i>Monilinia fructicola</i>	Peach brown rot.	260	<i>Cladosporium cucumerinum</i>	Scab.
211	<i>M. laxa</i>	Brown rot, blossom blight.	261	<i>Colletotrichum lagenarium</i>	Anthraxnose (except squash).
	<i>Filbert</i> (<i>Corylus</i> spp)		262	<i>Erysiphe cichoracearum</i>	Powdery mildew.
212	<i>Apioportha anomala</i>	Twig blight, canker.	263	<i>Fusarium oxysporum melonis</i>	Fusarium wilt (muskmelon).
213	<i>Armillaria mellea</i>	Root rot.	264	<i>F. oxysporum niveum</i>	Fusarium wilt (watermelon).
214	<i>Phyllactinia corylea</i>	Powdery mildew.	265	<i>F. solani cucurbitae</i>	Fusarium root rot.
	<i>Pecan</i> (<i>Carya illinoensis</i>)		266	<i>Mycosphaerella melonis</i>	Black rot.
215	<i>Cercospora fusca</i>	Brown leaf spot.	267	<i>Pseudoperonospora cubensis</i>	Downy mildew.
216	<i>Cladosporium effusum</i>	Scab.	268	<i>Verticillium albo-atrum</i>	Verticillium wilt.
217	<i>Gnomonia caryae pecanae</i>	Liver spot.		<i>Lettuce</i> (<i>Lactuca sativa</i>)	
218	<i>G. nerviseda</i>	Vein spot.	269	<i>Botrytis cinerea</i>	Gray mold.
219	<i>Mycosphaerella caryigena</i>	Downy spot.	270	<i>Bremia lactucae</i>	Downy mildew.
220	<i>M. dendroides</i>	Leaf blotch.		<i>Onion</i> (<i>Allium</i> spp)	
221	<i>Phymatotrichum omnivorum</i>	Cotton root rot.	271	<i>Botrytis</i> spp	Neck rot.
	<i>Walnut</i> (<i>Juglans regia</i>)		272	<i>Peronospora destructor</i>	Downy mildew.
222	<i>Armillaria mellea</i>	Root rot.	273	<i>Pyrenochaeta terrestris</i>	Pink rot.
223	<i>Ascochyta juglandis</i>	Ring spot.	274	<i>Urocystis cepulae</i>	Smut.
224	<i>Dothiorella gregaria</i>	Dieback, black sap.		<i>Pea</i> (<i>Pisum sativum</i>)	
225	<i>Exosporina fawcetti</i>	Branch wilt, canker.	275	<i>Aphanomyces euteiches</i>	Root rot.
226	<i>Gnomonia leptostyla</i>	Leaf blotch.	276	<i>Ascochyta pinodella</i>	Ascochyta foot rot.
227	<i>Phytophthora cactorum</i>	Crown rot.	277	<i>A. pisi</i>	Ascochyta leaf and pod spot.
Vegetable Crops			278	<i>Colletotrichum pisi</i>	Anthraxnose.
	<i>Asparagus</i> (<i>Asparagus officinalis</i>)		279	<i>Erysiphe polygoni</i>	Powdery mildew.
228	<i>Fusarium oxysporum</i>		280	<i>Fusarium oxysporum pisi</i> , strain 1	Fusarium wilt.
	<i>asparagi</i>	Wilt, root rot.	281	<i>F. oxysporum pisi</i> , strain 2	Near-wilt.
229	<i>Puccinia asparagi</i>	Rust.	282	<i>F. solani pisi</i>	Root rot.
	<i>Bean</i> (<i>Phaseolus vulgaris</i>)		283	<i>Mycosphaerella pinodes</i>	Mycosphaerella blight.
230	<i>Colletotrichum lindemuthianum</i>	Anthraxnose.	284	<i>Peronospora viciae</i>	Downy mildew.
231	<i>Erysiphe polygoni</i>	Powdery mildew.		<i>Pepper</i> (<i>Capsicum frutescens</i>)	
232	<i>Fusarium solani</i>	Root rot.	285	<i>Cercospora capsici</i>	Frog-eye leaf spot.
233	<i>Macrophomina phaseoli</i>	Ashy stem blight, charcoal rot, leaf spot, root rot.	286	<i>Gloeosporium piperatum</i>	Anthraxnose.
	<i>Uromyces phaseoli typica</i>	Rust.	287	<i>Phytophthora capsici</i>	Phytophthora blight.
234	<i>Bean</i> (<i>Phaseolus lunatus</i> macrocarpus)		288	<i>Potato</i> (<i>Solanum tuberosum</i>)	
235	<i>Colletotrichum truncatum</i>	Stem anthracnose.		<i>Alternaria solani</i>	Early blight.
236	<i>Diaporthe phaseolorum</i>	Pod blight, leaf spot.	289	<i>Fusarium</i> spp	Wilt and tuber rot.
237	<i>Macrophomina phaseolina</i>	Ashy stem blight, charcoal rot, leaf spot, root rot.	290	<i>Phytophthora infestans</i>	Late blight.
	<i>Phytophthora phaseoli</i>	Downy mildew.	291	<i>Streptomyces scabies</i>	Common scab.
238	<i>Beet</i> (<i>Beta vulgaris</i>)		292	<i>Verticillium albo-atrum</i>	Verticillium wilt.
239	<i>Aphanomyces cochlioides</i>	Black root, tip rot.		<i>Spinach</i> (<i>Spinacia oleracea</i>)	
240	<i>Cercospora beticola</i>	Cercospora leaf spot.	293	<i>Albugo occidentalis</i>	White rust.
241	<i>Fusarium</i> spp	Root rot, storage rot, wilt.	294	<i>Peronospora effusa</i>	Downy mildew.
242	<i>Peronospora schachtii</i>	Downy mildew.		<i>Sweetpotato</i> (<i>Ipomoea batatas</i>)	
243	<i>Pleospora betae</i>	Leaf spot, root rot.	295	<i>Endoconidiophora fimbriata</i>	Black rot.
244	<i>Uromyces betae</i>	Rust.	296	<i>Fusarium oxysporum batatas</i>	Wilt, stem rot.
	<i>Carrot</i> (<i>Daucus carota</i>)		297	<i>Monilochaetes infuscans</i>	Scurf.
245	<i>Alternaria dauci</i>	Leaf blight.	298	<i>Plenodomus destruens</i>	Foot rot.
246	<i>A. radicina</i>	Black rot.	299	<i>Streptomyces ipomoea</i>	Pox or soil rot.
247	<i>Cercospora carotae</i>	Blight, leaf spot.		<i>Tomato</i> (<i>Lycopersicon esculentum</i>)	
	<i>Celery</i> (<i>Apium graveolens dulce</i>)		300	<i>Alternaria solani</i>	Early blight.
248	<i>Cercospora apii</i>	Early blight.	301	<i>Colletotrichum phomoides</i>	Anthraxnose.
249	<i>Fusarium oxysporum apii</i>	Fusarium yellows.	302	<i>Fusarium oxysporum lycopersici</i>	Fusarium wilt.
250	<i>Septoria apii</i>	Late blight (large spot).	303	<i>Phoma destructiva</i>	Phoma rot.
251	<i>S. apii-graveolentis</i>	Late blight (small spot).	304	<i>Phytophthora infestans</i>	Late blight.
			305	<i>Septoria lycopersici</i>	Leaf spot.
			306	<i>Stemphylium solani</i>	Gray leaf spot.

/2/ Cabbage, cauliflower. /3/ Cucumber, muskmelon, squash, watermelon.

427. SELECTED FUNGAL PARASITES: FOREST TREES

Host Plant and Pathogen		Disease	Host Plant and Pathogen		Disease
1	Alaska-cedar (<i>Chamaecyparis nootkatensis</i>)		Alder (<i>Alnus</i> spp) (concluded)		
	<i>Gymnosporangium nootkatense</i>	Mountain ash-Alaska cedar rust.	6	<i>Taphrina amentorum</i>	Leaf blister.
2	Alder (<i>Alnus</i> spp)		7	<i>T. macrophylla</i>	Yellow leaf blister.
	<i>Cytospora pulcherrima</i>	Cytospora canker.	8	<i>T. occidentalis</i>	Leaf blister.
3	<i>Didymospora oregonensis</i>	Didymospora canker.	9	<i>T. robinsoniana</i>	Leaf blister.
4	<i>Erysiphe aggregata</i>	Powdery mildew.	10	<i>T. rugosa</i>	Leaf blister.
5	<i>Melampsorium alni</i>	Leaf rust.		<i>Arborvitae</i> (<i>Thuja orientalis</i>)	
			11	<i>Coryneum berckmanii</i>	Berckman's blight.
			12	<i>Gymnosporangium kernianum</i>	Witches'-broom rust.

427. SELECTED FUNGAL PARASITES: FOREST TREES (Continued)

Host Plant and Pathogen		Disease	Host Plant and Pathogen		Disease
13	Arborvitae (<i>Thuja orientalis</i>) (concluded) <i>Gymnosporangium nelsoni</i>	Hawthorne-western juniper rust.	82	Fir (<i>Abies</i> spp) (concluded) <i>Melampsora abietis-capraearum</i>	Needle rot.
	Ash (<i>Fraxinus</i> spp)		83	<i>Melampsorella cerastii</i>	Witches'-broom.
14	<i>Armillaria mellea</i>	Root rot.	84	<i>Melesia fructuosa</i> , <i>M. marginalis</i>	Needle rust.
15	<i>Cytospora annularis</i>	Cytospora canker.	85	<i>M. polypodophila</i>	Needle-witches'-broom rust.
16	<i>Fomes fraxinophilus</i>	White heart rot.	86	<i>Peridermium holwayi</i> , <i>P. ornamentale</i> , <i>P. rugosum</i>	Needle rust.
17	<i>Marssonina fraxini</i>	Leaf spot.	87	<i>Phacidium infestans</i> var. <i>abietis</i>	Needle blight.
18	<i>Mycosphaerella fraxinicola</i>	Leaf spot.	88	<i>Phomopsis boycei</i>	Phomopsis canker.
19	<i>Phymatotrichum omnivorum</i>	Phymatotrichum root rot.	89	<i>Polyporus abietinus</i>	White pitted sap rot.
20	<i>Polyporus hispidus</i>	Spongy white rot.	90	<i>P. balsameus</i>	Brown butt rot.
21	<i>Puccinia peridermiospora</i>	Leaf rust.	91	<i>P. dryadeus</i>	White root rot.
	Ash, mountain (<i>Sorbus americana</i>)		92	<i>P. schweinitzii</i>	Root and butt rot.
22	<i>Gymnosporangium aurantiacum</i>	Fusiforme rust of juniper.	93	<i>Poria subacida</i>	Butt rot.
23	<i>G. juniperinum</i>	Subglobose gall rust.	94	<i>Rehmellopsis balsamiae</i>	Tip blight.
24	<i>G. nidus-avis</i>	Witches'-broom and spindle shaped gall rust.	95	<i>Scleroderris abieticola</i>	Scleroderris canker.
	Basswood (<i>Tilia</i> spp)		96	<i>Spicaria anomala</i>	Brown stain of fir.
25	<i>Collybia velutipes</i>	Spongy white rot.	97	<i>Stereum chaillieti</i>	Patchy rot.
26	<i>Pholiota squarrosa adiposa</i>	Brown mottled rot.	98	<i>S. sanguinolentum</i>	Red heart rot.
27	<i>Uncinula clintonii</i>	Powdery mildew.	99	<i>Uredinopsis atkinsonii</i> , <i>U. ceratophora</i> , <i>U. longimucronata</i> , <i>U. macrosperma</i> , <i>U. mirabilis</i>	Needle rust.
	Beech (<i>Fagus grandifolia</i>)			Douglas-fir (<i>Pseudotsuga menziesii</i>)	
28	<i>Fomes fomentarius</i>	White mottled rot.	100	<i>Adelopus gaumanni</i>	Needle cast.
29	<i>F. igniarius nigricans</i>	Heart rot.	101	<i>Armillaria mellea</i>	Shoestring root rot.
30	<i>Nectria coccinea faginata</i>	Beech bark disease.	102	<i>Botrytis douglasii</i>	Gray mold blight.
31	<i>Phytophthora cactorum</i>	Phytophthora blight.	103	<i>Caliciopsis pinea</i>	Caliciopsis canker.
32	<i>Polyporus glomeratus</i>	Light-brown spongy heart rot.	104	<i>Chondropodium pseudotsugae</i>	Chondropodium canker.
33	<i>Poria obliqua</i>	Canker.	105	<i>Cytospora friesii</i>	Cytospora canker.
	Birch (<i>Betula</i> spp)		106	<i>Dasyscypha pseudotsugae</i>	Dasyscypha canker.
34	<i>Fomes fomentarius</i>	White mottled rot.	107	<i>Diplodia pinea</i>	Top damping off.
35	<i>F. igniarius laevigatus</i>	Heart rot and canker.	108	<i>Echinodontium tinctorium</i>	Brown stringy rot.
36	<i>Melampsorium betulinum</i>	Leaf rust.	109	<i>Fomes applanatus</i>	Mottle rot.
37	<i>Nectria galligena</i>	Nectria canker.	110	<i>F. laricis</i>	Brown trunk rot.
38	<i>Pholiota squarrosa adiposa</i>	Brown mottled rot.	111	<i>F. pini</i>	Red ring rot.
39	<i>Poria obliqua</i>	Canker.	112	<i>F. pinicola</i>	Brown cubical rot.
40	<i>Stereum murrayi</i>	Rot and canker.	113	<i>F. roseus</i>	Yellow-brown tap rot.
41	<i>Taphrina boycei</i> , <i>T. flava</i>	Yellow leaf blister.	114	<i>Melampsora albertensis</i>	Needle rust.
	Chestnut (<i>Castanea dentata</i>)		115	<i>Phacidium infestans</i> var. <i>abietus</i>	Needle blight.
42	<i>Endothia parasitica</i>	Chestnut blight.	116	<i>Phomopsis lokoyae</i>	Phomopsis canker.
43	<i>Fistulina hepatica</i>	Brown cubical rot.	117	<i>P. pseudotsugae</i>	Douglas-fir canker.
44	<i>Monochaetia desmazierii</i>	Leaf spot.	118	<i>Polyporus schweinitzii</i>	Root and butt rot.
45	<i>Marssonina ochroleuca</i>	Small leaf spot.	119	<i>Poria monticola</i>	Brown cubical rot.
46	<i>Polyporus spraguei</i>	Brown friable rot.	120	<i>P. weirii</i>	Laminated root rot.
	Cypress, Arizona (<i>Cupressus arizonica</i>)		121	<i>Rhododcline pseudotsugae</i>	Needle blight.
47	<i>Gymnosporangium cupressi</i>	Fusiform gall rust.	122	<i>Sparassis radicata</i>	Sparassis root rot.
	Cypress, Monterey (<i>Cupressus macrocarpa</i>)			Hemlock, eastern (<i>Tsuga canadensis</i>)	
48	<i>Coryneum cardinale</i>	Coryneum canker.	123	<i>Fomes robustus-tsugina</i>	White heart rot.
49	<i>Polyporus basilaris</i>	Brown cubical rot.	124	<i>Ganoderma lucidum</i>	White rot.
	Elm (<i>Ulmus</i> spp)		125	<i>Keithia tsugae</i>	Cedar leaf blight.
50	<i>Ceratostomella ulmi</i>	Dutch elm disease.	126	<i>Melampsora abietis canadensis</i> , <i>M. farlowii</i>	Needle rust.
51	<i>Chalaropsis thievallodes</i>	Chinese elm root rot.	127	<i>Polyporus borealis</i>	White mottled rot.
52	<i>Cytospora ambiens</i>	Cytospora canker.	128	<i>Pucciniastrum hydrangeae</i> , <i>P. myrtilli</i>	Needle rust.
53	<i>C. portinuludibunda</i>	Dieback.	129	<i>Rosellinia herpotrichoides</i>	Brown felt blight.
54	<i>Dothiorella ulmi</i>	Dieback.		Hemlock, western (<i>Tsuga heterophylla</i>)	
55	<i>Gloeosporium ulmicolum</i>	Leaf spot.	130	<i>Armillaria mellea</i>	Shoestring root rot.
56	<i>Gnomonia ulmea</i>	Leaf spot.	131	<i>Caecoma dubium</i>	Needle rust.
57	<i>Phlebospora ulmi</i>	Elm leaf spot.	132	<i>Echinodontium tinctorium</i>	Brown string rot.
58	<i>Phytophthora inflata</i>	Pit canker.	133	<i>Fomes annosus</i>	Root and butt rot.
59	<i>Pleurotus ulmaris</i>	Brown rot.	134	<i>F. pinicola</i>	Brown cubical rot.
60	<i>Sphaeropsis ulmicola</i>	Canker.	135	<i>F. robustus-tsugina</i>	White heart rot.
61	<i>Tubercularia</i> sp	Elm canker.	136	<i>Ganoderma oregonense</i>	White rot.
62	<i>Uncinula macrocarpa</i>	Powdery mildew.	137	<i>Uraecium holwayi</i>	Needle rust.
63	<i>Verticillium rhizophagum</i>	Verticillium root disease.		Hickory (<i>Hicoria</i> spp)	
64	<i>Verticillium</i> sp	Verticillium wilt.	138	<i>Microstroma juglandis</i>	Witches'-broom.
	Fir (<i>Abies</i> spp)			Incense-cedar (<i>Libocedrus decurrens</i>)	
65	<i>Adelopus gaumanni</i>	Swiss needle cast.	139	<i>Gymnosporangium libocedri</i>	Apple-incense cedar rust.
66	<i>Aleurodiscus amorphus</i>	Aleurodiscus canker.	140	<i>Polyporus amarus</i>	Pocket dry rot.
67	<i>Armillaria mellea</i>	Shoestring root rot.		Juniper (<i>Juniperus</i> spp)	
68	<i>Bifusella abietis</i> , <i>B. fauillii</i>	Needle cast.	141	<i>Fomes juniperinus</i>	Juniper pocket rot.
69	<i>Caecoma fauilliana</i>	Needle rust.	142	<i>F. subroseus</i>	Brown pocket rot.
70	<i>Calypsotheca goeppertiana</i>	Needle rust.	143	<i>Gymnosporangium aurantiacum</i>	Mountain ash, mountain juniper rust.
71	<i>Cephalosporium</i> sp	Cephalosporium canker.		<i>G. bermudianum</i>	Juniper rust.
72	<i>Corticium gelactinum</i>	Corticium rot.	144	<i>G. betheli</i>	Elongate gall rust of juniper.
73	<i>Cytospora abietis</i>	Cytospora canker.	145	<i>G. clavariaeforme</i>	Fusiform gall rust of juniper.
74	<i>Dasyscypha resinaria</i>	Dasyscypha canker.	146	<i>G. clavipes</i>	Fusiform gall rust.
75	<i>Fomes annosus</i>	Root and butt rot.	147	<i>G. corniculans</i>	Serviceberry, juniper rust.
76	<i>F. pini</i>	Red ring rot.	148	<i>G. davisi</i>	Chokeberry-mountain juniper rust.
77	<i>F. pinicola</i>	Brown cubical rot.	149	<i>G. effusum</i>	Fusiform gall rust.
78	<i>Hyalospora aspidiotus</i>	Needle cast.	150	<i>G. exiguum</i>	Hawthorne-alligator juniper rust.
79	<i>Hypoderma robustum</i>	Needle cast.	151		
80	<i>Hypodermella abietis concoloris</i> , <i>H. mirabilis</i> , <i>H. nervata</i>	Needle cast.			
81	<i>Lophodermium abietis</i> , <i>L. uncinatum</i>	Needle cast.			

427. SELECTED FUNGAL PARASITES: FOREST TREES (Continued)

Host Plant and Pathogen		Disease	Host Plant and Pathogen		Disease
152	Juniper (Juniperus spp) (concluded) Gymnosporangium externum	Porteranthus, fusiform gall rust of juniper.	225	Oak (Quercus spp) (concluded) Taphrina caerulescens	Oak leaf blister.
153	G. floriforme	Hawthorne-juniper rust.	226	Austrian pine (Pinus laricina-austriaca) [hard]	
154	G. globosum	Hawthorne-cedar rust.	227	Cronartium cerebrum	Eastern gall rust.
155	G. harnessianum	Serviceberry-western juniper rust.	228	C. comandrae	Comandra blister rust.
156	G. inconspicuum	Serviceberry-Utah twig rust.	229	Dothistroma pini	Needle blight.
157	G. juniperi-virginianae	Apple cedar rust.	230	Jack pine (Pinus banksiana) [hard]	
158	G. kernianum	Witches'-broom rust.	231	Chionectria cucurbitula	Burn blight.
159	G. multiporum	Utah juniper rust.	232	Coleosporium solidaginis	Needle rust.
160	G. nelsoni	Hawthorne-western juniper rust.	233	Cronartium cerebrum	Eastern gall rust.
161	G. trachysorum	Fusiform gall rust of juniper.	234	C. comandrae	Comandra blister rust.
162	G. tuberlatum	Globose gall rust of mountain juniper.	235	Hypodermella ampla, H. concolor	Needle cast.
163	G. vauqueliniae	Witches'-broom of vauquelinia.	236	Lenzites saepiaria	Brown cubical rot.
164	Keithia juniperi	Leaf blight.	237	Loblolly pine (Pinus taeda) [hard]	
165	Phomopsis juniperovora	Juniper blight.	238	Coleosporium apocynaceum, C. lacinariae, C. minutum	Needle rust.
166	Larch (Larix europaea)		239	Cronartium comandrae	Comandra blister rust.
167	Dasyctypha willkommii	European larch canker.	240	Hypoderma lethale	Needle spot.
168	Fomes pini	Red ring rot.	241	Lophodermium pinastri	Needle spot.
169	Melampsora bigelowii	Needle rust.	242	Lodgepole pine (Pinus contorta) [hard]	
170	Hypodermella laricis	Needle cast.	243	Atropellis pinicola, A. piniphila	Atropellis canker.
171	Melampsora bigelowii	Needle rust.	244	Coleosporium solidaginis	Needle rust.
172	M. medusae	Needle spot.	245	Cronartium comandrae	Comandra blister rust.
173	Larch (Larix occidentalis)		246	C. comptoniae	Sweet fern blister rust.
174	Fomes laricis	Brown trunk rot.	247	C. filamentosum	Paintbrush blister rust.
175	Hypodermella laricis	Needle cast.	248	C. harknessii	Western gall rust.
176	Melampsora bigelowii, M. medusae	Needle rust.	249	Elytroderma deformans	Needle cast.
177	Sparassis radicata	Sparassis root rot.	250	Fomes pini	Red ring rot.
178	Locust, black (Robinia pseudoacacia)		251	Hypodermella concolor, H. medusa, H. montivaga, H. montana	Needle cast.
179	Fomes rimosus	Yellow heart rot.	252	Peridermium weirii	Needle rust.
180	Fusicladium robiniae	Leaf spot.	253	Longleaf pine (Pinus palustris) [hard]	
181	Polyporus robinophilus	White heart rot.	254	Coleosporium apocynaceum	Needle rust.
182	Maple (Acer spp)		255	C. inconspicuum, C. lacinariae	Needle rust.
183	Cristulariella depraehens	Leaf spot and wilt.	256	Cronartium strobilinum	Pine cone rust.
184	Daedalea unicolor	Rot and canker.	257	Fomes pini	Red ring rot.
185	Daldinia concentrica	White rot.	258	Peridermium gutamalese	Needle rust.
186	Endoconidiophora virescens	Sapstreak.	259	Polyporus schweinitzii	Root and butt rot.
187	Eutypella parasitica	Eutypella canker.	260	Red pine (Pinus resinosa) [hard]	
188	Fomes connatus	Butt rot.	261	Armillaria mellea	Shoestring root rot.
189	F. ignarius nigricans	Heart rot.	262	Atropellis tingens	Atropellis canker.
190	Hydnum septentrionale	Soft spongy white rot.	263	Chionectria cucurbitula	Burn blight.
191	Hymenochaete agglutinans	Hymenochaete canker.	264	Coleosporium campanulae, C. solidaginis	Needle rust.
192	Hypoxylon blakei	Hypoxylon canker.	265	Dothistroma pini	Needle spot.
193	Nectria cinnabarina	Nectria dieback.	266	Fomes annosus	Butt rot.
194	N. galligena	Nectria canker.	267	Pellularia pullulans	Needle blight.
195	Phleospora aceris	Leaf spot.	268	Polyporus schweinitzii	Root and butt rot.
196	Phytophthora cactorum	Bleeding canker.	269	Pythium irregulare	Damping off.
197	Polyporus glomeratus	Rot and canker.	270	Rhizina inflata	Rhizina root rot.
198	Rhytisma acerinum	Tar spot.	271	Rhizoctonia solana	Damping off.
199	Schizoxylon microsporium	Schizoxylon canker.	272	Scotch pine (Pinus sylvestris) [hard]	
200	Stereum murrayi	Rot and canker.	273	Cronartium comandrae	Comandra blister rust.
201	Uncinula circinata	Powdery mildew.	274	Cronartium harknessii	Western gall rust.
202	Venturia acerina	Red-brown spot.	275	Sphaeropsis ellisii	Burn bright.
203	Verticillium albo-atrum	Verticillium wilt.	276	Shortleaf pine (Pinus echinata) [hard]	
204	Xylaria digitata	Xylaria root rot.	277	Caliciopsis pinea	Caliciopsis canker.
205	Oak (Quercus spp)		278	Coleosporium helianthi, C. inconspicuum	Needle rust.
206	Aleurodiscus oaksii	Smooth patch.	279	Cronartium cerebrum	Globose gall rust.
207	Armillaria mellea	Shoestring root rot.	280	Slash pine (Pinus elliottii) [hard]	
208	Cronartium cerebrum	Globose gall rust.	281	Atropellis tingens	Atropellis canker.
209	C. fusiforme	Southern fusiform rust.	282	Coleosporium apocynaceum	Needle rust.
210	C. strobilinum	Pine cone rust.	283	Cronartium fusiforme	Fusiform gall rust.
211	Daedalea quercina	Brown cubical rot.	284	C. strobilinum	Pine cone rust.
212	Endoconidiophora fagacearum	Oak wilt.	285	Fomes annosus	Root rot.
213	Fistulina hepatica	Brown cubical rot.	286	F. pini	Red ring rot.
214	Fomes everhartii	White heart rot.	287	Hypoderma lethale	Needle spot.
215	Gnomonia veneta	Anthraxnose.	288	Lophodermium pinastri	Needle spot.
216	Hydnum erinaceus	White rot.	289	Polyporus schweinitzii	Root and butt rot.
217	Morenoella quercina	Leaf spot.	290	Virginia pine (Pinus virginiana) [hard]	
218	Polyporus berkeleyi	White butt rot.	291	Atropellis piniphila	Atropellis canker.
219	P. croceus	White pocket rot.	292	Coleosporium inconspicuum	Needle rust.
220	P. dryophilus	Piped rot.	293	Fomes annosus	Root rot.
221	P. frondosus	Butt rot.	294	F. pini	Red heart rot.
222	P. hispidus	Heart rot and canker.	295	Peridermium appalacianum	Virginia pine rust.
223	P. spraguei	White rot.	296	Western yellow pine (Pinus ponderosa) [hard]	
224	P. sulphureus	Brown cubical rot.	297	Atropellis arizonica, A. piniphila	Atropellis canker.
225	Sphaerotheca lanestris	Witches'-broom.	298	Coleosporium solidaginis	Needle rust.
226	Sphaeropsis quercina	Sphaeropsis canker.	299	Cronartium comandrae	Comandra blister rust.
227	Stereum gausapatum	White mottled rot.	300	C. comptoniae	Sweet fern blister rust.
228	S. subpileatum	White pocket rot.	301	C. filamentosum	Paintbrush blister rust.
229	Strumella corynoidea	Strumella canker.	302	C. quercuum	Gall rust.

427. SELECTED FUNGAL PARASITES: FOREST TREES (Concluded)

Host Plant and Pathogen		Disease	Host Plant and Pathogen		Disease
Western yellow pine (<i>Pinus ponderosa</i>) [hard] (concluded)			Spruce, Engelmann (<i>Picea engelmannii</i>)		
291	<i>Cronartium harknessii</i>	Western gall rust.	353	<i>Chrysomyxa ledicola</i>	Needle rust.
292	<i>Dasyscypha ellisiaana</i>	<i>Dasyscypha</i> canker.	354	<i>C. pyrolae</i>	Spruce cone rust.
293	<i>Elytroderma deformans</i>	Witches'-broom and needle cast.	355	<i>C. weirii</i>	Needle rust.
294	<i>Fomes laricis</i>	Brown cubical rot.	356	<i>Echinodontium tinctorium</i>	Brown string rot.
295	<i>F. pini</i>	Red ring rot.	357	<i>Peridermium coloradense</i>	Witches'-broom.
296	<i>Hypodermella medusa</i>	Needle cast.	358	<i>Sparassia radicata</i>	Sparassia root rot.
297	<i>Lentinus lepideus</i>	Brown cubical rot.	Spruce, Norway (<i>Picea abies</i>)		
Eastern white pine (<i>Pinus strobus</i>), Sugar pine (<i>P. lambertiana</i>), Western pine (<i>P. monticola</i>) [soft]			359	<i>Ascochyta piniperda</i>	Needle spot.
298	<i>Armillaria mellea</i>	Shoestring root rot.	360	<i>Chrysomyxa cassandrae</i> , <i>C. ledi</i>	Needle rust.
299	<i>Atropellis pinicola</i>	<i>Atropellis</i> canker.	361	<i>C. pyrolae</i>	Spruce cone rust.
300	<i>Bifusella linearis</i>	Needle cast.	362	<i>Hymenochaete agglutinans</i>	Smothering disease.
301	<i>Caliciopsis piniae</i>	<i>Caliciopsis</i> canker.	363	<i>Peridermium coloradense</i>	Witches'-broom.
302	<i>Cronartium ribicola</i>	White pine blister rust.	364	<i>Phoma piceana</i>	Needle blight.
303	<i>Fomes annosus</i>	Root and butt rot.	Spruce, red (<i>Picea rubra</i>)		
304	<i>F. laricis</i>	Brown cubical rot.	365	<i>Ascochyta piniperda</i>	Needle spot.
305	<i>F. pini</i>	Red ring rot.	366	<i>Chrysomyxa cassandrae</i> , <i>C. ledi</i> , <i>C. empetri</i> , <i>C. ledicola</i>	Needle rust.
306	<i>Hypoderma desmazierii</i>	Needle cast.	367	<i>C. pyrolae</i>	Spruce cone rust.
307	<i>Lentinus lepideus</i>	Brown cubical rot.	368	<i>C. weirii</i>	Needle rust.
308	<i>Lophodermium pinastri</i>	Needle cast.	369	<i>Corticium galactinum</i>	Corticium rot.
309	<i>Neopeckia coulteris</i>	Brown felt blight.	370	<i>Lophodermium filiforme</i> , <i>L. picea</i>	Needle cast.
310	<i>Polyporus circinatus</i>	Red root and butt rot.	371	<i>Phoma piceina</i>	Needle blight.
311	<i>Phacidium planum</i>	Needle blight.	372	<i>Polyporus borealis</i>	White mottled rot.
312	<i>Sparassia radicata</i>	Sparassia root rot.	Spruce, Sitka (<i>Picea sitchensis</i>)		
Poplar (<i>Populus</i> spp)			373	<i>Chrysomyxa empetri</i>	Spruce rust.
313	<i>Armillaria mellea</i>	Shoestring root rot.	374	<i>C. ledicola</i> , <i>C. piperiana</i>	Needle rust.
314	<i>Ciborinia whetzelii</i>	Ink spot.	375	<i>Fomes laricis</i>	Brown cubical rot.
315	<i>Cytospora chrysosperma</i>	<i>Cytospora</i> canker.	376	<i>F. pini</i>	Red ring rot.
316	<i>Dothichiza populea</i>	<i>Dothichiza</i> canker.	377	<i>F. pinicola</i>	Brown cubical rot.
317	<i>Fomes applanatus</i>	White butt rot.	378	<i>Lentinus kauffmanii</i>	Brown pocket rot.
318	<i>F. fomentarius</i>	White mottled rot.	379	<i>Peridermium coloradense</i>	Witches'-broom.
319	<i>F. igniarius</i>	White heart rot.	380	<i>Poria monticola</i>	Brown cubical rot.
320	<i>Fusicladium radiosum</i>	Shoot blight.	Spruce, white (<i>Picea glauca</i>)		
321	<i>Hypoxylon pruinaum</i>	Hypoxylon canker.	381	<i>Chrysomyxa cassandrae</i> , <i>C. chioensis</i> , <i>C. empetri</i> , <i>C. ledi</i> , <i>C. ledicola</i>	Needle rust.
322	<i>Limospora tetraspora</i>	Leaf blight.	382	<i>C. pyrolae</i>	Spruce cone rust.
323	<i>Melampsora bigelowii</i> , <i>M. medusae</i> , <i>M. occidentalis</i>	Leaf spot.	383	<i>Peridermium coloradense</i>	Witches'-broom.
324	<i>Marssonina populi</i>	Leaf spot and shoot blight.	384	<i>Pucciniastrum americanum</i> , <i>P. arctium</i>	Needle rust.
325	<i>Nectria galligena</i>	<i>Nectria</i> canker.	385	<i>Rhizina inflata</i>	Rhizina root rot.
326	<i>Neofabraea populi</i>	<i>Neofabraea</i> canker.	Sycamore (<i>Platanus</i> spp)		
327	<i>Schlerotinia bifrons</i>	Ink spot.	386	<i>Endoconidiophora</i> sp	London plane canker stain.
328	<i>Septoria musiva</i>	<i>Septoria</i> canker.	387	<i>Gnomonia veneta</i>	Anthracocone.
329	<i>S. populicola</i>	Leaf spot.	Sweetgum (<i>Liquidambar styraciflua</i>)		
330	<i>Taphrina aurea</i>	Yellow leaf blister.	388	<i>Polyporus ludovicianus</i>	White pocket rot.
331	<i>T. johansonii</i>	Catkin blister.	389	<i>P. fissilis</i>	Butt rot.
332	<i>Trametes suaveolens</i>	Soft white rot.	Walnut (<i>Juglans nigra</i>)		
333	<i>Ucinula salicis</i>	Powdery mildew.	390	<i>Armillaria mellea</i>	Shoestring root rot.
334	<i>Valsa nivea</i> , <i>V. sordida</i>	<i>Valsa</i> canker.	391	<i>Fomes everhartii</i>	White heart rot.
335	<i>Xylaria digitata</i>	<i>Xylaria</i> root rot.	392	<i>Phymatotrichum omnivorum</i>	Phymatotrichum root rot.
Port-Orford-cedar (<i>Chamaecyparis lawsoniana</i>)			393	<i>Phytophthora cinnamomi</i>	Root rot.
336	<i>Phytophthora lateralis</i>	<i>Chamaecyparis</i> root rot.	White-cedar, Atlantic (<i>Chamaecyparis thyoides</i>)		
Red cedar, western (<i>Thuja plicata</i>)			394	<i>Gymnosporangium biseptatum</i>	Spindle-shaped gall rust.
337	<i>Coryneum thujinum</i>	Leaf blight.	395	<i>G. ellisii</i>	Witches'-broom rust.
338	<i>Fomes nigrolimitatus</i>	White pocket rot.	396	<i>G. hyalinum</i>	Frisiforme gall rust.
339	<i>Keithia thujina</i>	Cedar leaf blight.	397	<i>G. transformans</i>	Chokeberry-southern white cedar rust.
340	<i>Poria albipelleducia</i>	White ring rot.	White-cedar, northern (<i>Thuja occidentalis</i>)		
341	<i>P. asiatica</i>	Brown cubical rot.	398	<i>Coniphora puteana</i>	Brown cubial rot.
342	<i>P. wierii</i>	Laminated root rot.	399	<i>Keithia thujina</i>	Cedar leaf blight.
Redwood (<i>Sequoia sempervirens</i>)			Willow (<i>Salix</i> spp)		
343	<i>Poria albipelleducia</i>	White ring rot.	400	<i>Botryosphaeria ribis</i>	<i>Botryosphaeria</i> canker.
344	<i>P. sequoia</i>	Brown pocket rot.	401	<i>Cytospora pulcherrima</i>	<i>Cytospora</i> canker.
Spruce, black (<i>Picea mariana</i>)			402	<i>Fomes igniarius</i>	Heart rot.
345	<i>Chrysomyxa cassandrae</i> , <i>C. chioensis</i> , <i>C. ledi</i> , <i>C. ledicola</i>	Needle rust.	403	<i>Fusicladium saliciperidum</i>	Willow scab.
346	<i>C. pyrolae</i>	Spruce cone rust.	404	<i>Melampsora abietis-capraearum</i>	Leaf rust.
347	<i>Lophodermium filiforme</i> , <i>L. picea</i>	Needle cast.	405	<i>Physalospora miyabeana</i>	Black canker.
348	<i>Peridermium coloradense</i>	Witches'-broom.	406	<i>Polyporus squamosus</i>	White rot.
349	<i>Phacidium expansum</i>	Needle blight.	407	<i>Trametes suaveolens</i>	Soft white rot.
Spruce, blue (<i>Picea pungens</i>)			408	<i>Ucinula salicis</i>	Powdery mildew.
350	<i>Chrysomyxa cassandrae</i> , <i>C. ledi</i> , <i>C. ledicola</i>	Needle rust.	409	<i>Valsa nivea</i> , <i>V. sordida</i>	<i>Valsa</i> canker.
351	<i>C. pyrolae</i>	Spruce cone rust.	Yellow-poplar (<i>Liriodendron tulipifera</i>)		
352	<i>Peridermium coloradense</i>	Witches'-broom.	410	<i>Nectria magnoliae</i>	<i>Nectria</i> canker.

428. SELECTED PROTOZOAN AND HELMINTHIC PARASITES: VERTEBRATES

Part I: PARASITES OF MAN

Parasite	Geographic Distribution	Infective Stage	Port of Entry	Immature Stage	Location in Man		Reservoir Host of Definitive Stage	Other Obligate Host or Vector	Identification				
					Definitive Stages				Stage	Source			
					Primary Site	Secondary Site							
Protozoa													
1 Entamoeba coli	World-wide; most common in warm climates.	4-nucleate cyst.	Mouth ¹ .	None described.	Lumen, large intestine.	None.	Monkey(?).	None.	Trophozoite, cyst.	Feces.			
2 E. histolytica					Wall, large intestine.	Other viscera, skin.	Monkey, dog, rat(?).			Feces, visceral or skin abscesses.			
3 Balantidium coli					None.	Swine, monkey(?).							
4 Giardia lamblia					Duodenal crypts.	Gallbladder(?).	Rat(?).			Sheep(?).	Feces.		
5 Leishmania brasiliensis	W. Hemisphere from S. Mexico to N. Argentina	Leptomonad.	Skin ² .	None described.	Skin.	Mucous membranes.	Dog, possibly other mammals.	Sandfly (Phlebotomus).	Leishmanial. Leptomonad.	Reticulo-endothelial cells, skin, viscera. Culture.			
6 L. donovani	China, India, Africa, Mediterranean area, S. America.					Reticulo-endothelium (fundamental).	Dog, rodents.						
7 L. tropica	W. India, Middle East, Near East, N. Africa.					Mucous membranes, (rare).							
8 Trichomonas vaginalis	Relatively common, both sexes.	Trophozoite (only stage known).	Vulva ¹ or urethra.	None described.	Vaginal folds.	Bladder.	None.	None.	Trophozoite.	Urine, vaginal smear.			
9 Trypanosoma cruzi	Western Hemisphere, from U.S.A. to N. Argentina.	Metacyclic trypanosome.	Skin ³ , conjunctiva.		Skin.	In tissues, blood.	Many mammals.	Triatomid bugs.	Trypanosomal. Leishmanial. Crithidial.	Blood, tissues. Culture.			
10 T. gambiense	W. and Cent. Africa.		Skin ² .			Blood, lymph nodes, CNS.	Cattle(?).	Tsetse fly (Glossina)	Trypanosomal.	Blood, gland juice, spinal fluid.			
11 T. rhodesiense	Cent. and E. Africa.				Wild game, mammals.								
12 Plasmodium falciparum	Temperate or warm climates.	Sporozoite.	Skin ² .	Schizonts in hepatic parenchyma.	Exo-erythrocytic foci.	Erythrocytes.	None.	Mosquito (Anopheles spp)	Trophozoites, schizonts, gametocytes.	Blood.			
13 P. malariae													
14 P. vivax													
15 Toxoplasma gondii	World-wide.	Trophozoite.	Unknown.	None known.	Reticulo-endothelium, many parenchymal cells.	Brain, retina.	Many mammals and birds.	None known.	Trophozoite or pseudo-cyst.	Focal areas of necrosis.			
Platyhelminthes													
16 Diphyllbothrium latum	N. temperate zones; Argentinian, Chilean lakes.	Sparganum larva in fish flesh.	Mouth.	Develops in small intestine.	Attached to small intestine.	None known.	Dog, bear, cat.	Diaptomus, Cyclops; fresh-water fish.	Eggs.	Feces.			
17 Dipylidium caninum	Warm climates.	Larva in hemo-coel of dog flea.				None.	Dog, cat.	Dog, cat, human flea.	Proglottids.	Feces.			
18 Echinococcus granulosus	World-wide; common in southern S. America.	Eggs in dog's excreta.		Develops in liver, lungs.		Hydatid cysts in human viscera.	Dog, wild relatives.	Sheep, cattle, swine (alternating with dog).	Hydatid cyst with scolices.	Aspiration. Exploratory operation.			
19 Hymenolepis diminuta	Warm and temperate climates.	Larva in hemo-coel of insect.		Develops in duodenum, small intestine.		None known.	Rat, mouse.	Rodent flea, grain beetles, meal moths, etc.	Eggs, proglottids.	Feces ⁴ .			
20 H. nana		Egg.	Develops in duodenal villi.	None.	Swine.			Eggs.					
21 Taenia saginata		Cysticercus larva in beef.	Develops in small intestine.					Cattle.	Proglottids, eggs.				
22 T. solium	World-wide.	Cysticercus larva in pork; egg.			(Cysticercus larvae in various viscera)	None.	Swine.						
23 Clonorchis sinensis	Sino-Japanese and Indo-Chinese areas.	Larva encysted in flesh of fresh-water fish.	Mouth ⁵ .	In transit from duodenum to bile ducts.	Distal bile ducts.	Pancreatic ducts (rare).	Many fish eating mammals.	Snail, fresh-water fish.	Eggs.				
24 Fasciola hepatica	Sheep-raising countries.	Larva encysted on water plants.			Proximal bile ducts.	Abdominal wall(?), lungs, brain.	Herbivores.	Snail, moist vegetation.					
25 Fasciolopsis buski	Oriental countries.	Larva encysted on water plants.		Develops in duodenum, jejunum.	Attached to duodenum, jejunum.	None.	Swine.	Snail, water plants.					

26	<i>Paragonimus westermani</i>	Sino-Jap. areas, S.W. Pacific islands; northern S. America.	Larva encysted in soft tissues of crabs, crayfish.	Mouth ⁵ .	In transit from duodenum to lungs.	Lungs, near bronchioles.	Abdominal viscera, brain.	Cat, dog, swine, other animals.	Snail, crab and crayfish; sputum of man.	Sputum, feces.	
27	<i>Schistosoma hematobium</i>	Africa, Near East, Middle East, southern Portugal.	Cercaria free in fresh water.	Skin ⁶ .	Migrates in blood vessels.	Vesical venous plexus.	Pelvic organs, rectum, lungs, CNS.	Gerbil.	Bulinid snail.	Urine, feces.	
28	<i>S. japonicum</i>	China, Japan, Philippines, Formosa, Celebes.				Mesenteric venules.	Liver, lungs, brain.	Many mammals.	Oncomelaniid snail.	Eggs.	Feces.
29	<i>S. mansoni</i>	Africa, Arabia, Brazil, Guianas, Venezuela, West Indies.						Monkey (rarely).	Planorbisid snail.		
Nematoda											
30	<i>Ancylostoma brasiliense</i>	Limited distribution in warm climates.	Filariform larva.	Skin ¹ .	Larvae migrate from skin via blood, lungs to epiglottis, GI tract.	Attached to small intestine.	None.	Dog, cat.	None.	Eggs, (larvae).	Feces (cutaneous tunnels.)
31	<i>A. duodenale</i>	Palaearctic region ⁷ , western S. America.						None.		Eggs.	Feces.
32	<i>Ascaris lumbricoides</i>	World-wide; more common in warm climates.	Fully embryonated egg.	Mouth ¹ .	Larvae migrate.	Lumen, small intestine.	Various viscera.	Swine(?)	Eggs.	Feces.	
33	<i>Dracunculus medinensis</i>	Warm climates Eastern Hemisphere.	3rd stage larva in Cyclops.	Mouth ⁵ .	In viscera.	Gravid ? migrates to skin.	None known.	Fur-bearing mammals.	Cyclops.	Gravid ♀.	Ruptured skin blister.
34	<i>Enterobius vermicularis</i>	World-wide; common in children.	Fully embryonated egg.	Mouth ¹ .	In transit down small intestine.	Attached to cecum, appendix.	Female genital tract, perianal folds.	None.	Eggs, adults.	Anal swab, anus.	
35	<i>Loa loa</i>	Tropical Africa.	Filariform larva.	Skin ² .	Migrates in subcutaneous tissues.	Orbit, conjunctiva of eye.	None.	None.	Mango-fly (Chrysops).	Microfilariae (sheathed).	Diurnal blood.
36	<i>Necator americanus</i>	Warm climates.		Skin ¹ .	Larvae migrate.	Attached to small intestine.			None.	Eggs.	Feces.
37	<i>Onchocerca volvulus</i>	Tropical Africa, Mexico, Guatemala, E. Venezuela, Dutch Guiana.		Skin ² .	Adults in subcutaneous nodules. Larvae in skin, may invade eye tissues.	None known.			Blackflies (Simulium).	Microfilariae (un-sheathed).	Skin biopsy.
38	<i>Strongyloides stercoralis</i>	Warm, moist climates.		Skin ¹ .	Larvae migrate.	Within intestinal mucosa.	Lungs.	Dog, chimpanzee.	None.	Larvae.	Feces, duodenal aspirate.
39	<i>Wuchereria bancrofti</i>	Warm climates.	Larvae encysted in pork muscle.	Skin ² .	Migrate in lymphatics.	Lymphatics of lower trunk, legs.	Lymphatics of upper trunk.	None.	Mosquito (Aedes, Culex).	Microfilariae (sheathed).	Usually nocturnal blood.
40	<i>Trichinella spiralis</i>	World-wide; common in United States.		Mouth ⁵ .	Enter duodenal mucosa.	In duodenal mucosa.	Larvae migrate, encysted in striped muscle.	Swine, bear, walrus.	None.	Larvae.	Compressed or digested muscle.
41	<i>Trichiuris trichiuris</i>	Warm, moist climates.	Fully embryonated egg.	Mouth ¹ .	In transit down small intestine.	Attached to cecum, appendix.	Colon, rectum.	Swine(?), ape, monkey.		Eggs.	Feces.

/1/ By direct or indirect contact with body excreta containing the parasite. /2/ From proboscis of insect vector at time of skin puncture to obtain blood or tissue juice from host. /3/ From feces of insect vector while feeding on blood or tissue juice of host. /4/ Also in sputum for *P. westermani*. /5/ From infected food or contaminated water taken into the mouth. /6/ In contact with infested water. /7/ Tropical and subtropical: Africa, Asia, Europe, U.S.A.

Part II: PARASITES OF ANIMALS OTHER THAN MAN

Parasite	Geographic Distribution	Definitive Host	Intermediate Host	Primary Location in Definitive Host	Disease; Type of Damage
Protozoa					
1 <i>Anaplasma marginale</i>	N., S., and C. America, Asia, Africa, France.	Cattle.	None. Mechanical transfer by ticks, tabanid flies, instruments.	Erythrocytes.	Anemia, icterus, fever, extreme splenomegaly.
2 <i>Babesia bigemina</i>	N., S., and C. America, Africa, Europe, Asia, Pacific Islands, Australia.	Cattle.	Tick (Boophilus Rhipicephalus).	Erythrocytes.	Texas fever; anemia, hemoglobinuria.
3 <i>Eimeria tenella</i>	World-wide.	Chicken.	None.	Cecal cells.	Hemorrhagic enteritis.
4 <i>E. zurnii</i>	World-wide.	Cattle.	None.	Intestinal cells.	Enteritis, dysentery.
5 <i>Histomonas meleagridis</i>	World-wide.	Domestic fowl, ruffed grouse, quail, partridge.	None. Transmitted in Heterakis gallinae eggs.	Cecum, liver.	Enterohepatitis, necrosis, ulceration.

428. SELECTED PROTOZOAN AND HELMINTHIC PARASITES: VERTEBRATES (Concluded)
Part II: PARASITES OF ANIMALS OTHER THAN MAN (Concluded)

Parasite	Geographic Distribution	Definitive Host	Intermediate Host	Primary Location in Definitive Host	Disease; Type of Damage
Protozoa (concluded)					
6 Trypanosoma congolense	Africa.	Cattle, other ruminants, dog.	Tsetse fly (Glossina)	Blood.	Anemia.
Cestoidea					
7 Moniezia expansa		Sheep, goat, cattle, other ruminants.	Grass mite (several spp).		Intestinal irritation, slight damage.
8 Taenia pisiformis	World-wide.	Dog, fox, wolf, cat.	Hare, rabbit, rat, squirrel.	Small intestine.	Slight enteritis, anal pruritus.
Nematoda					
9 Ascaridia gali ¹		Chicken, guinea fowl, turkey, goose, wild birds.		Small intestine.	Emaciation.
10 Dictyocaulus viviparus ²	World-wide.	Cattle, deer.	None.	Bronchus, bronchiole.	Catarrhal inflammation, coughing, emaciation.
11 Dirofilaria immitis ³	Europe, India, China, Japan, Australia, N. and S. America, Pacific Islands.	Dog, cat, fox, wolf.	Mosquito (Aedes, Anopheles, Culex); flea (Ctenocephalides, Pulex).	Heart, pulmonary artery; microfilariae in blood.	Emaciation, dyspnea, cough, edema.
12 Haemonchus contortus ⁴	World-wide.	Sheep, goat, cattle, other ruminants.		Abomasum, small intestine.	Anemia, emaciation.
13 Strongylus vulgaris	Warm climates.	Horse, other equines.	None.	Large intestine.	Anemia, edema, digestive disturbance, emaciation; larvae form aneurisms in mesenteric arteries.

/1/ Roundworm. /2/ Lungworm. /3/ Heartworm. /4/ Stomachworm.

429. SELECTED PARASITIC NEMATODES: PLANTS

Most of the nematode parasites of plants are found in largest numbers in close association with roots of plants, or in the upper 16 inches of soil formerly occupied by plant roots. In general, plant parasites can be distinguished from saprophagous or predaceous forms, also found in the soil, by the presence of a protrusile spear or stylet used to puncture and feed on plant cells. The soil is not the only habitat, however, for nematodes. Some live in fresh waters of rivers, lakes and ponds. Others live only in the ocean. Many are parasites of animals and of man.

Nematode	Geographical Distribution ¹	Hosts ²	Feeding Habits ³	Symptoms ⁴	Control
1 Awl nematode (Dolichodorus heterocephalus)	Florida, Georgia, Michigan.	Celery, corn, tomato, bean, Chinese water-chestnut; many other plants growing in wet locations.	Vagrant ectoparasites of root tips, sides of succulent roots.	Devitalized root tips, small lesions on sides of roots; sometimes extensive root destruction.	Soil fumigation.
2 Bulb and stem nematode (Ditylenchus spp and closely related forms)	Widespread; temperate zones.	Over 300 different plants, including narcissus, hyacinth, iris, onion, clover, alfalfa, oats, phlox, potato.	Vagrant endoparasites of bulbs, stems, leaves, occasionally roots.	Twisting, wrinkling, distortion of stems and flowers; necrosis and destruction of bulb tissues.	Hot-water treatment of bulbs, corms; crop rotation; field sanitation; methyl bromide fumigation of infected onion and clover seed.
3 Burrowing nematode (Radopholus similis)	India, Indonesia, Formosa, Philippines, Hawaii, Brazil, C. America, Jamaica, La., Fla.	About 50 different plants including citrus, canna, coffee, tea, banana, avocado, black pepper, sugarcane, rice.	Vagrant endoparasites of roots.	Root lesions and disintegration.	Hot water treatment of infected citrus nursery stock; pulling of affected trees, then soil fumigation.
4 Chrysanthemum nematode (Aphelenchoides ritzema-bosi)	N. America, Europe.	About 50 different plants including chrysanthemum, delphinium, phlox, verbena, zinnia, strawberry.	Vagrant endoparasites of buds and foliage.	Crinkled, distorted leaves and leaf spots.	Hot water treatment of dormant plants; parathion sprays.
5 Citrus nematode (Tylenchulus semi-penetrans)	Fla., Tex., Calif., most citrus fruit-growing regions.	Most Citrus spp and closely related genera; olive.	Females are sedentary parasites, partly external, of roots.	Extensive necrosis, discoloration of cortex of small roots.	Plant uninfected stock on clean land.
6 Coconut palm nematode (Aphelenchoides cocophilus)	W. Indies, Br. Guiana, Honduras, Panama, Venezuela.	Coconut, date, and oil palms.	Vagrant endoparasites of roots, trunk (near periphery), leaf petioles.	Disintegration of trunk tissues (causing "red ring") and of root cortex.	No established control measures.
7 Dagger nematodes (Xiphinema spp)	World-wide.	Many plants, trees, shrubs, including laurel oak, pecan, rose, clove, strawberry, corn, oats, some grasses.	Vagrant ectoparasites of root tips, sides of succulent roots.	Devitalized root tips, necrosis of small roots, gall-like swellings, clusters of small stubby branches.	Soil fumigation.
8 Golden nematode of potatoes (Heterodera rostochiensis)	Europe, Bolivia, Peru; in N. America on Long Island, N. Y.	Potato, tomato, several other solanaceous plants.	Sedentary parasites, internal in early stages, becoming largely external as adults; attack roots, other underground parts.	Stunting of plant, decrease in size of root system, but often increase in number of small branch rootlets.	Crop rotation; soil fumigation.
9 Grass nematode (Anguina spp)	Europe, N. America.	Several Agrostis species; other grasses and cereals.	Larvae, ectoparasites around growing point; adults, endoparasites of flower primordia.	Abnormal flowers developing into galls.	Crop rotation; planting gall-free seed.
10 Lance nematode (Hoplolaimus coronatus)	N. America, Philippines.	Many plants including corn, sugarcane, cotton, St. Augustine and other lawn grasses.	Vagrant internal or partly external parasites of roots.	Lesions leading to complete destruction and sloughing off of cortex.	Soil fumigation.

11	Meadow or root lesion nematode (<i>Pratylenchus</i> spp)	World-wide.	Many plants, including tobacco, corn, small grains, cotton, alfalfa, strawberry, trees and shrubs.	Vagrant endoparasites of roots and tubers ⁵ .	Small brown root lesions. Causes "brown root-rot" of tobacco.	Crop rotation, tobacco; row fumigation with D-D.
12	Pin nematodes (<i>Pratylenchus</i> spp)	Netherlands, Br. Isles, Hawaii, N. America.	Many plants, including pineapple, oat, wheat, cowpea, alfalfa, cabbage, cucumber, okra, radish, celery, fig trees.	Vagrant ectoparasites of roots and other underground structures.	Stunting of plants from root injury and retarded root growth.	Fumigation somewhat effective.
13	Potato rot nematode (<i>Ditylenchus destructor</i>)	Europe, Idaho, Wisconsin, Prince Edward Isl.	Potato, carrot, sweetpotato; tulip, iris.	Vagrant endoparasites of tubers, and to some extent of roots.	Destruction of tuber tissues, causing sunken areas, followed by rot.	Crop rotation; planting of clean seed; soil fumigation.
14	Rice root nematode (<i>Radopholus oryzae</i>)	Indonesia, Japan, rice-growing areas of S. E. Asia, Louisiana, Texas.	Rice, various grasses, and related monocotyledonous plants.	Vagrant endoparasites of roots.	Root lesions, destruction of cortex; root hairs; in Indonesia associated with "mentek," a rice root-rot.	No established control measures.
15	Ring nematodes (<i>Cricanemoides</i> spp)	Widespread.	Many plants; reported as injuring peach trees and peanut vines.	Semi-sedentary ectoparasites of roots, other underground parts.	Small lesions, stunting of plant.	Soil fumigation.
16	Root knot nematodes (<i>Meloidogyne</i> spp)	World-wide; most common in warm climates.	Over 1800 plants; hosts of individual species more restricted.	Sedentary endoparasites of roots, other underground parts.	Swellings, galls, often local necrosis of tissues; increase or reduction of branch rootlets.	Annual crops: rotation and fumigation. Planting of resistant varieties; hot-water treatment of bulbs, corms, tubers.
17	Soybean cyst nematode (<i>Heterodera glycines</i>)	Japan, China, Wilmington area of N. Carolina.	Soybean, adzuki bean, kidney bean. Snapbeans, annual lespedeza vetch.	Sedentary parasites of roots, internal in early stages, external as adults.	General stunting of plants, reduction in size of root system. Causes a disease known as "yellow dwarf" in Japan and China.	Crop rotation; soil fumigation.
18	Spiral nematodes (<i>Rotylenchus</i> and <i>Helicotylenchus</i> spp)	Widespread, in tropical and subtropical regions.	Many kinds of plants: ornamental, grass, bean, cowpea, pineapple.	Vagrant ectoparasites, occasionally endoparasites of roots and other underground parts.	Stunting of plant from retarded root growth; lesions may occur.	Soil fumigation.
19	Spring crimp nematode of strawberries (<i>Aphelenchoides fragariae</i>)	Europe, Br. Isles, Massachusetts, Connecticut, Delaware, Maryland.	Strawberry.	Vagrant ectoparasites of buds between young developing leaves.	Small, crinkled, distorted foliage.	Set new beds with uninfested plants.
20	Sting nematode (<i>Beloniellus gracilis</i>)	S. Atlantic states.	Bean, beet, cabbage, celery, citrus, corn, cotton, cowpea, grass, millet, okra, onion, peanut, pine seedling, soybean, strawberry.	Vagrant ectoparasites of root tips, sides of succulent roots, other underground parts.	Devitalized root tips, root lesions, causing many short stubby branched roots, severely stunted plants.	Soil fumigation.
21	Stubby root nematodes (<i>Trichodorus</i> spp)	Widespread; important in S. E. U.S.A., S. Calif.	Many plants, including beet, celery, cabbage, cauliflower, chayote, fig.	Vagrant ectoparasites of root tips.	Devitalized root tips causing numerous short, stubby branch rootlets.	No satisfactory control known.
22	Stunt nematodes (<i>Tylenchorhynchus</i> spp)	Apparently widespread.	Many plants including cotton, oats, tobacco, wheat, sugar cane.	Mostly external, occasionally internal vagrant parasites of roots.	Stunting of plant from retarded root growth.	Tobacco: row fumigation with ethylene dibromide.
23	Sugar beet nematode (<i>Heterodera schachtii</i>)	Europe, Australia, Canada, U.S.A.	Over 100 plants, including sugar beet, table beet, mangelswurzel, cabbage, cauliflower, kale, broccoli, turnip, rutabaga, mustard.	Sedentary parasites of roots, other underground parts; internal in early stages, external as adults.	Stunting of plant, overall decrease in size of root system, often increase in number of small branch rootlets.	Crop rotation; soil fumigation with D-D before planting (sugar beet).
24	Summer crimp nematode of strawberries (<i>Aphelenchoides besseyi</i>)	S.E. U. S. A., Maryland-Texas.	Strawberry, rice.	Vagrant ectoparasites of buds and growing points between young developing leaves.	Small, crinkled, distorted foliage.	Set new beds with uninfested plants. Hot-water treatment or methyl bromide fumigation for rice seed.
25	Wheat nematode (<i>Anguina tritici</i>)	S. and E. Asia, Egypt, Australia, Europe, S. Atlantic states.	Wheat, rye, emmer, spelt.	Larvae, ectoparasites around growing point; adults, endoparasites of flower primordia.	Stunted plants, distorted foliage, galls instead of seed.	Plant gall-free seed (galls may be removed by salt brine flotation or mechanical separators).

- /1/ Information on the geographical distribution of plant parasitic nematodes is fragmentary and incomplete, even for the best known species. Undoubtedly distribution is far wider than indicated.
- /2/ Species of nematodes within a given genus vary in their ability to attack plants; some have a rather wide host range; others are highly host-specific, attacking only one or two crop plants.
- /3/ Although parasitic nematodes feed on all parts of plants, feeding habits and particular tissues attacked vary, depending on the species, host plant and stage of development of the host and parasite. /4/ Symptoms of nematode damage are often difficult to distinguish from those caused by other organisms or by poor growing conditions; hence it is important in making a diagnosis to find the nematode in the diseased tissues or soil adjacent to the roots of affected plants. /5/ All species in the genus *Pratylenchus* are root parasites except *P. mahogani* and *P. scribneri*, observed in diseased mahogany wood and potato tubers, respectively.

430. VIRAL AGENTS: PLANT DISEASE

Except where otherwise indicated, the common name of the disease is identical with that of the virus.

	Virus	Distribution	Principal Plant Host	Principal Insect Vector	Other Means of Transmission	Symptoms
1	Abacá bunchy-top (Marmor abacá)	Philippine Islands	Abacá (<i>Musa textilis</i>)	Aphid (<i>Pentalonia nigronervosa</i>)	Grafting, except bark grafting; seeds.	Chlorotic spots; reduction in leaf size.
2	Abutilon-variegation (<i>M. abutilon</i>)	West Indies	Flowering maple (<i>Abutilon striatum</i>)			Systemic chlorotic mottling.
3	Alfalfa-mosaic (<i>M. medicaginis</i>)	United States	Alfalfa (<i>Medicago sativa</i>)	Aphid (<i>Macrosiphum pisi</i> , <i>M. solanifolii</i>)	Leaf rubbing.	Systemic chlorotic mottling, often masked.
4	Aster-yellows (<i>Chlorogenus callistephi</i>)	United States, Bermuda	Aster (<i>Callistephus chinensis</i>)	Leafhopper (<i>Macrostelus divinus</i> and others)	Grafting; dodder.	Leaves chlorotic, small; shoots many, erect; flowers virescent.
5	Bean-mosaic (Marmor phaseoli)	Almost world-wide	Bean (<i>Phaseolus vulgaris</i>)	Aphid (including <i>Aphis rumicis</i>)	Leaf abrasion; seeds.	Systemic chlorotic mottling.
6	Bean-mosaic, southern (<i>M. laesiofaciens</i>)	Southern United States	Bean (<i>P. vulgaris</i>)		Leaf rubbing; seeds.	Some varieties mottle; others show localized or systemic necrosis.
7	Beet-yellows (<i>Corium betae</i>)	Belgium, Holland	Beet (<i>Beta vulgaris</i>)	Aphid (including <i>Myzus persicae</i> and <i>Aphis fabae</i>)		Leaves yellow, thick, brittle; necrosis in secondary phloem.
8	Cassava-mosaic (<i>Ruga bemisiae</i>)	Africa, Java	Cassava (<i>Manihot utilissima</i>)	White-fly (<i>Bemisia nigeriensis</i> , <i>B. gossypiperda</i>)		Leaves distorted, mottled; plants stunted; side-branches numerous.
9	Cauliflower-mosaic (Marmor cruciferarum)	United States, England	Cauliflower (<i>Brassica oleracea</i>)	Aphid (including <i>Brevicoryne brassicae</i>)	Leaf abrasion.	Systemic chlorotic mottling; leaves distorted; plant dwarfed.
10	Clover club-leaf (<i>Aureogenus clavifolium</i>)	United States, (New Jersey)	Clover, crimson (<i>Trifolium incarnatum</i>)	Leafhopper (<i>Agalliopsis novella</i>)		Plant dwarfed; leaves small, yellowed or reddened at margins.
11	Cotton leaf-curl (<i>Ruga gossypii</i>)	The Sudan, Nigeria	Cotton (<i>Gossypium hirsutum</i>)	White-fly (<i>Bemisia gossypiperda</i>)	Grafting.	Leaves pale-spotted, puckered, unsymmetrical; internodes shortened.
12	Cranberry false-blossom (<i>Chlorogenus vaccinii</i>)	Eastern United States, Canada	Cranberry (<i>Vaccinium macrocarpon</i>)	Leafhopper (<i>Ophiola striatula</i>)	Dodder.	Flowers small, erect, streaked; calyx enlarged; fruit small.
13	Cucumber-mosaic (Marmor cucumeris)	Almost world-wide	Cucumber (<i>Cucumis sativus</i>)	Aphid (including <i>Myzus persicae</i> , <i>Aphis gossypii</i>)	Leaf rubbing; dodder.	Leaves mottled, distorted, small; plant stunted; fruits mottled.
14	Cucurbit-mosaic (<i>M. astrictum</i>) ¹	England	Cucumber (<i>C. sativus</i>)		Leaf rubbing.	Chlorotic mottling and distortion of foliage; plant stunted.
15	Dahlia-mosaic (<i>M. dahliae</i>)	United States, Holland, Germany, England	Dahlia (<i>Dahlia pinnata</i>)	Aphid (<i>M. persicae</i>)	Grafting.	Systemic chlorotic mottling or masked symptoms.
16	Lettuce-mosaic (<i>M. lactucae</i>)	World-wide	Lettuce (<i>Lactuca sativa</i>)	Aphid (<i>M. persicae</i> , <i>Macrosiphum gel</i>)	Leaf abrasion; seeds.	Clearing of veins, followed by systemic chlorotic mottling.
17	Maize-streak (<i>Fractilinea maidis</i>)	Africa	Corn (<i>Zea mays</i>)	Leafhopper (<i>Cicadulina mbila</i> , <i>C. zeae</i> , <i>C. storeyi</i>)		Chlorotic spotting and streaking of leaves.
18	Onion yellow-dwarf (Marmor capae)	United States, Germany, New Zealand, U.S.S.R.	Onion (<i>Allium cepae</i>)	Aphid (including <i>Aphis rumicis</i> , <i>A. maidis</i>)	Leaf rubbing.	Leaves yellowed, crinkled; plants dwarfed; bulbs small; seeds few.
19	Peach phony-disease (<i>Nanus mirabilis</i>)	Southeastern United States	Peach (<i>Prunus persica</i>)	Leafhopper (including <i>Homalodisca triquetra</i>)	Root grafting.	Foliage abnormally green; tree dwarfed; fruit small.
20	Peach-rosette (<i>Carpophthora rosettae</i>)	United States	Peach (<i>P. persica</i>)		Budding; dodder.	Stems short with dwarfed leaves; veins thickened; tree dies soon.
21	Peach X-disease (<i>C. lacerans</i>)	United States	Peach (<i>P. persica</i>)	Leafhopper (including <i>Colladonus</i> spp)	Budding.	Leaves light green, tattered; old leaves drop; fruit bitter.
22	Peach-yellows (<i>Chlorogenus persicae</i>)	Eastern United States, Eastern Canada	Peach (<i>P. persica</i>)	Leafhopper (<i>Macropsis trimaculata</i>)	Budding.	Leaves chlorotic; shoots erect, thin, numerous; tree dies soon.
23	Peanut-rosette (Marmor arachidis)	Africa, Madagascar, Java	Peanut (<i>Arachis hypogaea</i>)	Aphid (<i>Aphis laburni</i>)	Grafting.	Leaves small, chlorotic or mottled; internodes short; seeds few.
24	Potato aucuba-mosaic (<i>M. aucuba</i>)	United States, Europe, British Isles	Potato (<i>Solanum tuberosum</i>)	Probably aphid (<i>Myzus persicae</i>)	Leaf rubbing.	Yellow mottling of foliage; some necrosis in tubers.
25	Potato leafroll (<i>Corium solani</i>)	Wherever potatoes are grown	Potato (<i>S. tuberosum</i>)	Aphid (especially <i>M. persicae</i>)	Grafting.	Leaves thick, leathery, rolled, starchy; plant small; tubers few.
26	Potato mild-mosaic (Marmor solani)	United States, England, Holland	Potato (<i>S. tuberosum</i>)	Aphid (<i>Aphis abbreviata</i> and <i>M. persicae</i>)	Leaf rubbing.	Mild chlorotic mottling or masked symptoms in most varieties.

27	Potato-mottle (<i>Annulus dubius</i>)	World-wide	Potato (<i>Solanum tuberosum</i>)		Leaf rubbing; root and leaf contacts.	No obvious disease, or very mild chlorotic mottling.
28	Potato spindle-tuber (<i>Acrogenus solani</i>)	United States, Canada	Potato (<i>S. tuberosum</i>)	Aphid (<i>Myzus persicae</i> , <i>Macrosiphum solanifolii</i>)	Leaf rubbing; seed-piece cutting.	Leaves small, erect, dark green; plant brittle; tubers tapered.
29	Potato-veinbanding (<i>Marmor epsilon</i>)	United States, Brazil, England, France	Potato (<i>S. tuberosum</i>)	Aphid (especially <i>Myzus persicae</i>)	Leaf rubbing.	Chlorotic mottling, necrotic stem-streak, or no obvious disease.
30	Potato witches'-broom (<i>Chlorogenus solani</i>)	United States, U.S.S.R.	Potato (<i>S. tuberosum</i>)		Tuber-core and stem grafts.	Leaves small, pale; branches numerous, spindly; tubers small.
31	Potato yellow-dwarf (<i>Aureogenus vastans</i>)	United States, Canada	Potato (<i>S. tuberosum</i>)	Leafhopper (<i>Aceratagallia sanguinolenta</i>)	Leaf abrasion in some hosts; grafting.	Leaves yellowed; plant dwarfed; tubers few, small, often cracked.
32	Rice-dwarf (<i>Fractilinea oryzae</i>)	Japan, Philippine Islands	Rice (<i>Oryza sativa</i>)	Leafhopper (including <i>Nephotettix apicalis</i>)		Leaves chlorotic, spotted, streaked; internodes and roots short.
33	Sandal-spike (<i>Chlorogenus santali</i>)	Southern India	Sandal (<i>Santalum album</i>)	Leafhopper (<i>Jassus indicus</i>)	Grafting, except root grafting.	Leaves small; internodes short; flowers eventually suppressed.
34	Strawberry yellow-edge (<i>Marmor marginans</i>)	United States, England, France, New Zealand	Strawberry (<i>Fragaria hybrids</i>)	Aphid (<i>Aphis fragaefolii</i>)	Grafting.	Central leaves dwarfed, yellow-edged, lacking red color.
35	Sugar beet curly-top (<i>Ruga verrucosans</i>)	Western North America	Sugar beet (<i>Beta vulgaris</i>)	Leafhopper (<i>Eutettix tenellus</i>)	Grafting; dodder.	Leaves curled; enations on veins; plant stunted; rootlets many.
36	Sugar cane chlorotic streak (<i>Fractilinea quarta</i>)	United States, Java, Queensland, Hawaii, Puerto Rico	Sugar cane (<i>Saccharum officinarum</i>)	Leafhopper (<i>Draeculacephala portola</i>)		Long, narrow, white longitudinal streaks in leaves; yield reduced.
37	Sugar cane Fiji-disease (<i>Galla fijiensis</i>)	Australia and islands of the Pacific	Sugar cane (<i>S. officinarum</i>)	Leafhopper (<i>Perkinsiella saccharicida</i> , <i>P. vastatrix</i>)	Sugar cane Fiji-disease.	Leaves short, crumpled, darkened; galls on veins; roots dwarfed.
38	Sugar cane mosaic (<i>Marmor sacchari</i>)	Nearly everywhere sugar cane is grown	Sugar cane (<i>S. officinarum</i>)	Aphid (including <i>Aphis maidis</i>)	Needle puncture.	Systemic chlorotic mottling; vacuolate intracellular bodies.
39	Tobacco-etch (<i>M. erodens</i>)	United States	Tobacco (<i>Nicotiana tabacum</i>)	Aphid (especially <i>Myzus persicae</i>)	Leaf rubbing.	Systemic chlorotic mottling with traces of whitish etching.
40	Tobacco leaf-curl (<i>Ruga tabaci</i>)	Africa, India, Sumatra, Formosa	Tobacco (<i>N. tabacum</i>)	White-fly (<i>Bemisia gossypiperda</i>)	Grafting.	Leaves curled, wrinkled; veins thick; enations; plant stunted.
41	Tobacco-mosaic (<i>Marmor tabaci</i>)	World-wide	Tobacco (<i>N. tabacum</i>)		Leaf rubbing; dodder; soil.	Systemic chlorotic mottling; some distortion of leaves.
42	Tobacco-necrosis (<i>M. lethale</i>)	England, Scotland, Australia	Tobacco (<i>N. tabacum</i>)		Leaf rubbing; soil.	Necrosis in mid-rib and veins of lower leaves in winter.
43	Tobacco-ringspot (<i>Annulus tabaci</i>)	United States	Tobacco (<i>N. tabacum</i>)		Leaf rubbing; seeds of petunia.	Necrotic ringlike primary and secondary lesions; later recovery.
44	Tomato bushy-stunt (<i>Marmor dodecahedron</i>)	British Isles	Tomato (<i>Lycopersicon esculentum</i>)		Leaf rubbing; dodder.	Foliage yellowed, plant stunted; axillary buds stimulated.
45	Tomato spotted-wilt (<i>Lethum australiense</i>)	Almost world-wide	Tomato (<i>L. esculentum</i>)	Thrips <i>tabaci</i> , <i>Frankliniella moultoni</i> , <i>F. schultzei</i>	Leaf abrasion.	Bronze-ring lesions; necrosis or mottling; fruit discolored.
46	Turnip-mosaic (<i>Marmor brassicae</i>)	United States, New Zealand, England	Turnip (<i>Brassica rapa</i>)	Aphid (<i>Brevicoryne brassicae</i> , <i>Myzus persicae</i>)	Leaf rubbing.	Leaves mottled and distorted; plant stunted.
47	Wheat-mosaic (<i>M. tritici</i>)	United States, Japan	Wheat (<i>Triticum aestivum</i>)		Leaf abrasion.	Systemic chlorotic mottling; dwarfing; vacuolate inclusions.
48	Wheat streak-mosaic (<i>M. virgatum</i>)	United States, Canada	Wheat (<i>T. aestivum</i>)	Mite (<i>Aceria tulipae</i>)	Leaf abrasion.	Systemic chlorotic mottling and streaking of leaves.
49	Winter-wheat mosaic (<i>Fractilinea tritici</i>) ²	U.S.S.R.	Wheat (<i>T. aestivum</i>)	Leafhopper (<i>Deltocephalus striatus</i>)		Chlorotic mottling; phloem necrosis; vacuolate inclusions.
50	Wound-tumor (<i>Aureogenus magnivena</i>)	United States	Clover, crimson (<i>Trifolium incarnatum</i>)	Leafhopper (<i>Agalliopsis novella</i> , <i>Agallia constricta</i>)		Experimentally, veins thickened; enations; plant dwarfed.

/1/ Agent of "English cucumber-mosaic" disease. /2/ Agent of "Russian winter-wheat mosaic" disease.

431. SELECTED FUNGAL PARASITES: MAN

Part I: SUPERFICIAL MYCOSES

Fungus	Diseases Produced	Natural Occurrence	Microscopic Appearance in Skin	Microscopic Appearance in Nail	Microscopic Appearance in Hair	Microscopic Appearance of Culture on Sabouraud's Agar
1 <i>Cladosporium werneckii</i>	<i>Tinea nigra palmaris</i>		Pigmented, light brown to dark green, branching, septate hyphae which may develop closely septate, swollen cells and chlamydospores.	None.	None.	Pigmented hyphae which produce blastospores laterally and 1 to 3 septate conidia in clusters or in short chains from apiculi or short conidiophores.
2 <i>Epidermophyton floccosum</i>	<i>Tinea pedis</i> <i>T. cruris</i> <i>T. unguium</i>		Abundant, branching, septate hyphae which segment into chains of arthrospores.	Branching, septate hyphae which segment into chains of arthrospores.	None.	Macroconidia abundant, clavate, 2 to 6 cells, blunt-tip, smooth thin walls; occur in clusters of 2 or 3. No microconidia. Abundant chlamydospores.
3 <i>Malassezia furfur</i>	<i>Tinea versicolor</i>		Clusters of spherical, thick-walled, budding cells (3 to 8 μ) and short irregular hyphae.	None.	None.	No culture method available.
4 <i>Microsporum audouinii</i>	<i>Tinea capitis</i> <i>T. corporis</i>	Dog (rare) Monkey (rare)	Branching, septate hyphae which may segment into chains of arthrospores.	None.	Ectothrix. Sheath of small spores (2-3 μ).	Mycelium with chlamydospores. Microconidia infrequent, clavate, 2.5 to 4 x 3 to 6 μ . Macroconidia rare, rudimentary, and ill-formed.
5 <i>Microsporum canis</i>	<i>Tinea capitis</i> <i>T. corporis</i> <i>T. barbae</i> <i>T. unguium</i>	Cat ¹ Dog ¹ Horse Monkey		Rare.		Macroconidia numerous, 8 to 15 cells, spindle-shape, thick rough walls, 8 to 15 x 40 to 150 μ . Microconidia few, clavate, 2 to 4 x 3 to 6 μ .
6 <i>Microsporum gypsum</i>	<i>Tinea capitis</i> <i>T. corporis</i>	Cat Dog ¹ Horse ¹ Monkey Mouse Rat Soil ¹		None.	May be as above; more commonly large-spored ectothrix (5-8 μ).	Macroconidia numerous, ellipsoid, thin, rough walls, 4 to 6 cells, 8 to 12 x 30 to 50 μ . Microconidia few, clavate.
7 <i>Nocardia minutissima</i>	<i>Erythrasma</i>		Delicate, branching filaments (1 μ or less in diameter), readily fragment into coccoid and bacillary forms.	None.	None.	No culture method available.
8 <i>Piedraia hortai</i>	Black piedra		None.	None.	Nodule on hair shaft consists of brown, dichotomously branched, closely septate hyphae (4 to 8 μ in diameter) and asci containing 2 to 8 ascospores.	Dark, thick-walled, closely septate hyphae; chlamydospores, asci and ascospores are rare.
9 <i>Trichophyton concentricum</i>	<i>Tinea imbricata</i>		Abundant branching, septate hyphae which may segment into chains of arthrospores.	None.	None.	Septate, branching irregular mycelium with chlamydospores, pectinate hyphae, and favic chandeliers.
10 <i>Trichophyton ferrugineum</i>	<i>Tinea capitis</i> <i>T. corporis</i>		Branching, septate hyphae which may segment into chains of arthrospores.	None.	Ectothrix. Sheath of small arthrospores (2-3 μ).	Irregular mycelium with hyphal swellings and many chlamydospores.
11 <i>Trichophyton gallinae</i>	Favus of poultry ¹ and wild birds <i>Tinea capitis</i> <i>T. corporis</i>	Primarily a disease of poultry	Branching, septate hyphae. (Rare in man.)	None.	None.	Macroconidia usually numerous, clavate, 2 to 10 cells, smooth, slightly thickened walls. Microconidia few, small, pyriform to elongate.
12 <i>Trichophyton megnini</i>	<i>Tinea barbae</i> <i>T. capitis</i> <i>T. unguium</i>	Cattle Dog(?)	Branching, septate hyphae.	Branching, septate hyphae which may segment into chains of arthrospores.	Endothrix. Chains of large spherical arthrospores (6 to 8 μ).	Microconidia numerous, small, pyriform to elongate. Macroconidia rare, slightly clavate, 2 to 8 cells.
13 <i>Trichophyton mentagrophytes</i>	<i>Tinea pedis</i> <i>T. cruris</i> <i>T. corporis</i> <i>T. capitis</i> <i>T. unguium</i> <i>T. barbae</i>	Cat Cattle Chinchilla Dog ¹ Guinea pig ¹ Horse ¹ Monkey Mouse ¹ Muskat Rabbit Rat ¹	Branching, septate hyphae which may segment into chains of arthrospores.	Branching, septate hyphae which segment into chains of arthrospores.	Ectothrix. Chains of small arthrospores (3-5 μ).	Microconidia numerous, subspherical to pyriform, in terminal clusters or singly along the hyphae. Macroconidia clavate thick walls, 2 to 5 cells, 4 to 6 x 10 to 50 μ .

14	Trichophyton rubrum	Tinea pedis T. unguium T. cruris T. corporis T. barbae T. capitis	Cow (rare) Dog (rare)	Branching, septate hyphae which may segment into chains of arthrospores.		Ectothrix. Chains of large arthrospores (about 5µ).	Microconidia numerous singly along the hyphae and in clusters. Macroconidia infrequent, pencil-shaped thin walls, 4 to 6 x 10 to 50µ.
15	Trichophyton schoenleinii	Favus Tinea capitis T. corporis T. unguium	Dog (rare)	Abundant hyphae which may segment into chains of arthrospores throughout cellular debris of scutulum.	Branching, septate hyphae which segment into chains of arthrospores.	Endothrix. Mycelium, occasional arthrospore and numerous air bubbles inside hair.	Irregular mycelium, chlamydospores, hyphal swellings, pectinate hyphae, and favic chandeliers.
16	Trichophyton tonsurans	Tinea capitis T. corporis T. unguium				Endothrix. Large spores in chains (4-7.5µ).	Microconidia numerous, clavate along sides of hyphae or on short conidiophores. Spore-bearing hyphae stains poorly with LPCB. Numerous chlamydospores.
17	Trichophyton verrucosum	Tinea corporis T. capitis T. barbae	Cattle ¹ ; rare in dog, donkey, dromedary, goat, horse, sheep	Branching, septate hyphae which may segment into chains of arthrospores.	None.	Ectothrix. Chains of large arthrospores (5-10µ).	Irregular mycelium. Abundant chlamydospores. Microconidia and macroconidia present on thiamine-enriched media. Best growth at 37°C.
18	Trichophyton violaceum	Tinea capitis T. corporis T. barbae T. unguium			Branching, septate hyphae with segment into chains of arthrospores.	Endothrix. Chains of large arthrospores (4-7.5µ).	Irregular mycelium. Abundant chlamydospores and hyphal swellings. Microconidia rare.
19	Trichosporon beigellii	White piedra		Not affected.	None.	Nodule on hair shaft consists of hyphae which segment into spherical to rectangular cells (2 to 8 µ). Budding cells present.	Hyphae segment into rectangular to spherical arthrospores. Budding cells present.

1/ Host or site of most common occurrence.

Part II: DEEP MYCOSES

Fungus	Disease	Geographical Distribution	Occurrence in Nature		Organs and Tissues Frequently Attacked	Susceptible Laboratory Animals	Microscopic Appearance in		
			Animal Host	Saprophytic Occurrence			Tissue	Culture at 25°C	Culture at 37°C
1 Actinomyces bovis (A. israeli)	Actinomycosis (Lumpy jaw)	World-wide	Cattle Deer Dog Horse Swine	Man (often); obligate parasite	Cervico-facial region, lung, bone, cecum, appendix, liver	Hamster Mouse	Granules of filamentous, branching, Gram-positive hyphae (1 µ or less in width). Club-shaped accretions on tips of hyphae may be present.	Grows slowly.	Anaerobic, filamentous, branching, Gram-positive hyphae (1 µ or less in width).
2 Allescheria boydii (Monosporium apiospermum) Aspergillus spp (?) Madurella spp Indiella spp Cephalosporium spp Glenospora spp (?) Penicillium spp (?) Sterigmatocystis sp (?) Phialophora jeanselmei	Mycetoma (Maduremycosis; Madura foot)	World-wide; more frequent in tropics	Dog	Soil (A. boydii, P. jeanselmei)	Feet, hands, cutaneous and subcutaneous tissue, bone	Mouse (A. boydii)	Oval, irregular shaped granules (0.5 to 2 mm) made up of segmented branched hyphae (2 to 4 µ in diameter) and chlamydospores.	Allescheria boydii - mycelium with ovoid to pyriform conidia (5 to 7 x 8 to 10 µ) borne singly at ends of long conidiophores. Dark brown, thin-walled perithecia (50 to 200 µ in diameter) containing evanescent asci and elliptical ascospores. Coremia occasionally present.	Similar to cultures at 25°C.
3 Aspergillus spp (A. fumigatus)	Aspergillosis	World-wide	Birds	Grain Soil	Ear, sinus, orbit, vagina, lung, brain	Birds Guinea pig Rabbit	Fragments of septate hyphae and spherical, green conidia.	Conidiophore forms vesicle at tip. Surface covered with sterigmata bearing long chains of conidia.	Similar to growth at 25°C.
4 Blastomyces brasiliensis (Paracoccidioides brasiliensis)	South American blastomycosis (Paracoccidioides granuloma; Lutz-Splendore-de-Almeida's disease)	South America Central America	Not known	Not known	Mouth, lung, lymph node, gastro-intestinal tract	Guinea pig Hamster Mouse	Multiple budding, thick-walled cells (10 to 60 µ).	Mycelium with rare oval conidia (3 to 5 µ).	Similar to the forms observed in tissue.
5 Blastomyces dermatitidis	North American blastomycosis	U.S.A. Canada Mexico	Dog Horse	Not known	Skin, lung, bone	Guinea pig Mouse	Single budding, thick-walled cells (8 to 15 µ).	Mycelium with oval to pyriform conidia (3 to 5 µ) on conidiophores or attached directly to hyphae.	Similar to the forms observed in tissue.

431. SELECTED FUNGAL PARASITES: MAN (Concluded)

Part II: DEEP MYCOSES (Concluded)

Fungus	Disease	Geographical Distribution	Occurrence in Nature		Organs and Tissues Frequently Attacked	Susceptible Laboratory Animals	Microscopic Appearance in		
			Animal Host	Saprophytic Occurrence			Tissue	Culture at 25°C	Culture at 37°C
6 <i>Candida albicans</i> (<i>Monilia albicans</i>)	Candidiasis (Moniliasis; thrush; mycotic vulvovaginitis)	World-wide	Poultry	Man (often) Soil (rare)	Mucous membranes, nail, skin, bronchus, lung	Guinea pig Mouse Rabbit Rat	Oval to spherical budding cells (2 to 4 μ) and frequently hyphae which may show clusters of blastospores attached at septations.	Oval to spherical single budding cells (2 to 4 μ). Pseudohyphae and hyphae. Clusters of budding cells often at septations. Thick-walled chlamydospores (6 to 9 μ) on special medium.	Similar to growth at 25°C.
7 <i>Coccidioides immitis</i>	Coccidioidomycosis (Coccidioidal granuloma; valley fever; Posada-Wernicke's disease)	Arid S.W. U.S.A. Northern Mexico Chaco region, S. America	Cattle Dog Gorilla Monkey Rodents Sheep	Soil	Lung, skin, bone, meninges	Guinea pig Hamster Mouse Other rodents	Thick-walled spherules (20 to 60 μ) containing endospores (2 to 5 μ).	Mycelium with arthrospores (2.5 to 3 x 3 to 4 μ).	Similar to growth at 25°C. Under special conditions with special media, tissue spherules obtained in vitro.
8 <i>Cryptococcus neoformans</i> (<i>Torula histolytica</i>)	Cryptococcosis (Torulosis; European blastomycosis; Busse-Buschke's disease)	World-wide	Cat Cattle Dog Horse	Soil Pigeon droppings	Central nervous system, lung, skin, bone	Mouse Rat	Spherical, single budding, thick-walled cells (5 to 20 μ) surrounded by a wide, gelatinous capsule.	Similar to cells seen in tissue. ¹ Abortive hyphae may be seen on primary isolation.	Similar to cells seen in tissue.
9 <i>Geotrichum</i> sp	Geotrichosis	World-wide	Rodents	Soil Milk products	Mouth, intestinal tract, bronchus, lung	Not known	Oblong to rectangular cells with somewhat rounded ends (4 to 8 μ).	Mycelium with segments into rectangular arthrospores. Germ tube forms at corners.	Similar to growth at 25°C.
10 <i>Histoplasma capsulatum</i>	Histoplasmosis (Reticulo-endothelial cytomycosis; Darling's disease)	At least 24 countries of the world	Cat Cattle Dog Horse Mouse Rat Skunk	Soil, especially from avian habitats	Lung, liver, spleen, lymph nodes, mucous membranes, adrenal, kidney	Guinea pig Hamster Mouse	Intracellular oval, budding cells (1 to 5 μ).	Delicate mycelium with thin-walled, subspherical to pyriform conidia (2 to 5 μ) and thick-walled, tuberculated conidia 8 to 20 μ .	Budding cells (1 to 5 μ); must be grown on enriched medium.
11 <i>Hormodendrum pedrosoi</i> <i>H. compactum</i> <i>H. dermatitidis</i> <i>Phialophora verrucosa</i>	Chromoblastomycosis (Chromomycosis; verrucous dermatitis)	World-wide; more frequent in tropics	Not known	Soil, wood (<i>H. dermatitidis</i> , <i>P. verrucosa</i>)	Usually on lower extremities, cutaneous and subcutaneous tissue, lymphatics	Mouse Rat	Single or clustered, spherical, thick-walled, dark brown cells (6 to 12 μ) which multiply by splitting not budding. theca type-conidia borne acropleurously on swollen, club-like conidiophore. Phialophora type-conidia borne within a terminal cup-like structure on a flask-shaped conidiophore.	Three types of sporulation characterize this group of fungi: <i>Hormodendrum</i> type-conidia in branching chains arising terminally from conidiophore. <i>Acro-</i> from conidiophore.	Similar to cultures at 25°C.
12 <i>Mucor</i> spp (<i>Rhizopus oryzae</i> , <i>R. arrhizus</i> , <i>Absidia corymbifera</i>)	Mucormycosis	Probably world-wide	Birds Cattle Dog Horse Swine	Soil	Lung, brain, eye, intestinal tract	Diabetic rabbit	Nonseptate, coenocytic hyphae (6 to 15 μ in width).	Broad, coenocytic mycelium with brown sporangioophores.	Similar to growth at 25°C.
13 <i>Nocardia asteroides</i> <i>N. brasiliensis</i> <i>N. madurae</i> <i>N. pelletieri</i> <i>N. paraguayensis</i>	Nocardiosis (Actinomycotic mycetoma; Madura foot)	World-wide; more frequent in tropics	Cattle Dog	Soil	Lung, brain, cutaneous and subcutaneous tissue	Guinea pig Mouse	Granules of Gram-positive, branching, delicate hyphae. Occasionally not in granule form. <i>N. asteroides</i> and <i>N. brasiliensis</i> are partially acid-fast.	Delicate, branching hyphae (1 μ or less in width) which may or may not fragment into bacillary forms of varying length.	Similar to growth at 25°C.
14 <i>Rhinosporidium seeberi</i>	Rhinosporidiosis	World-wide; more frequent in India & Ceylon	Cow Horse Mule	Not known	Mucous membranes, nose, eye, vagina, penis, skin	Not known	Thick-walled spherule (50 to 350 μ) with pore, containing up to 16,000 endospores (7 to 9 μ).	No culture method available.	
15 <i>Sporotrichum schenckii</i>	Sporotrichosis	World-wide	Cat Cow Dog Horse Mouse Mule Rat	Mine timbers Plants Soil	Hands, feet, cutaneous and subcutaneous tissue, lymphatics	Hamster Mouse Rat	Rarely seen without special stains. Gram-positive, cigar-shaped or spherical to oval, usually intracellular, budding cells (3 to 5 μ). Asteroid forms rare.	Delicate (2 μ in width) hyphae. Pyriform to spherical conidia (2 to 4 x 2 to 6 μ) borne in clusters on lateral branches or laterally along the hyphae.	Cigar-shaped, spherical or oval budding cells. Must be grown on enriched medium.

¹/ Not true of some strains which may be weakly encapsulated in vitro, giving culture a different gross appearance similar to many of the common yeasts.

432. POPULATION, REGISTERED DEATHS AND DEATH RATES, BY RACE AND SEX: U.S.A., 1906-1954

Population estimated as of July 1 for 1906-39, 1941-49 and 1951-54, and enumerated as of April 1 for 1940 and 1950. Rates are per 1000 population in each specified group.

Year	Population of Continental United States ¹	Number of States ⁴	Population ⁵	Death-registration States ²									
				Deaths ³									
				Number					Rate				
				Total	White		Non-white		Total	White		Non-white	
					Male	Female	Male	Female		Male	Female	Male	Female
1 1954	162,414,000	48	161,195,000	1,481,000 ⁶	748,390 ⁶	559,760 ⁶	95,680 ⁶	77,170 ⁶	9.2 ⁶	10.5 ⁶	7.7 ⁶	11.4 ⁶	8.7 ⁶
2 1953	159,629,000	48	158,306,000	1,517,541	766,703	569,132	100,397	81,309	9.6	11.0	8.0	12.2	10.1
3 1952	157,022,000	48	155,755,000	1,496,838	753,571	561,451	100,356	81,460	9.6	11.0	8.0	12.5	9.6
4 1951	154,360,000	48	153,384,000	1,482,099	747,049	555,920	98,184	80,946	9.7	11.0	8.0	12.5	9.8
5 1950	151,132,000	48	150,697,361	1,452,454	731,366	544,719	96,383	79,986	9.6	10.9	8.0	12.5	9.9
6 1949	149,188,000	48	148,665,000	1,443,607	726,169	542,679	95,122	79,637	9.7	11.0	8.1	12.5	10.0
7 1948	146,631,000	48	146,093,000	1,444,337	725,818	544,771	95,113	78,635	9.9	11.2	8.3	12.7	10.1
8 1947	144,126,000	48	143,446,000	1,445,370	726,104	548,789	92,130	78,347	10.1	11.4	8.5	12.5	10.3
9 1946	141,389,000	48	140,054,000	1,395,617	697,323	535,014	88,366	74,914	10.0	11.2	8.5	12.2	10.0
10 1945	139,928,000	48	132,481,000	1,401,719	697,698	536,191	90,365	77,465	10.6	12.5	8.6	13.5	10.5
11 1944	138,397,000	48	132,885,000	1,411,338	697,731	541,098	92,130	80,379	10.6	12.2	8.8	13.8	11.1
12 1943	136,739,000	48	134,245,000	1,459,544	721,777	559,110	95,708	82,949	10.9	12.2	9.2	14.0	11.6
13 1942	134,860,000	48	133,920,000	1,385,187	685,468	524,476	94,986	80,257	10.3	11.4	8.7	14.0	11.4
14 1941	133,402,000	48	133,121,000	1,397,642	685,672	527,839	99,361	84,770	10.5	11.4	8.9	14.8	12.2
15 1940	131,820,000	48	131,669,000	1,417,269	690,901	540,322	100,102	85,944	10.8	11.6	9.2	15.1	12.6
16 1939	130,879,718	48	130,879,718	1,387,897	672,047	535,031	96,830	83,989	10.6	11.3	9.2	14.7	12.4
17 1938	129,824,939	48	129,824,939	1,381,391	665,559	529,872	99,343	86,617	10.6	11.3	9.2	15.2	12.9
18 1937	128,824,829	48	128,824,829	1,450,427	702,630	552,157	106,204	89,436	11.3	12.0	9.6	16.4	13.4
19 1936	128,053,180	48	128,053,180	1,479,228	712,126	566,253	109,313	91,536	11.6	12.3	9.9	16.9	13.9
20 1935	127,250,232	48	127,250,232	1,392,752	671,298	536,061	100,022	85,371	10.9	11.6	9.5	15.6	13.0
21 1934	126,373,773	48	126,373,773	1,396,903	670,476	536,671	102,119	87,587	11.1	11.7	9.6	16.0	13.5
22 1933	125,578,763	48	125,578,763	1,342,106	641,725	520,673	95,587	84,121	10.7	11.2	9.3	15.1	13.1
23 1932	124,840,471	47	118,903,899	1,293,269	614,093	508,377	90,413	80,386	10.9	11.3	9.6	15.4	13.5
24 1931	124,039,648	47	118,148,987	1,307,273	621,120	504,255	96,510	85,386	11.1	11.5	9.6	16.5	14.5
25 1930	123,076,741	47	117,238,278	1,327,240	625,792	511,092	100,888	89,468	11.3	11.7	9.8	17.4	15.3
26 1929	121,769,939	46	115,317,450	1,369,757	642,463	533,027	103,028	91,239	11.9	12.2	10.4	18.0	15.8
27 1928	120,501,115	44	113,636,160	1,361,987	637,063	531,206	101,828	91,890	12.0	12.3	10.8	18.0	16.2
28 1927	119,038,062	42	107,084,532	1,211,627	572,061	478,297	84,636	76,633	11.3	11.6	10.0	17.2	15.6
29 1926	117,399,225	41	103,822,683	1,257,256	590,852	502,998	86,180	77,226	12.1	12.3	10.8	18.7	16.9
30 1925	115,831,963	40	102,031,555	1,191,809	559,356	476,144	82,041	74,268	11.7	11.8	10.4	18.2	16.6
31 1924	114,113,463	39	99,318,098	1,151,076	539,303	458,314	80,571	72,888	11.6	11.8	10.3	17.9	16.3
32 1923	111,949,945	38	96,788,197	1,174,065	549,623	478,478	75,636	70,328	12.1	12.3	11.0	17.0	16.0
33 1922	110,054,778	37	92,702,901	1,083,952	507,567	443,885	68,360	64,140	11.7	11.9	10.7	15.7	14.8
34 1921	108,541,489	34	87,814,447	1,009,673	475,172	420,421	58,095	55,985	11.5	11.6	10.6	15.7	15.4
35 1920	106,466,420	34	86,079,263	1,118,070	521,440	469,419	64,696	62,515	13.0	13.0	12.1	17.8	17.5
36 1919	105,062,747	33	83,157,982	1,072,263	502,968	442,468	64,217	62,610	12.9	13.0	11.8	18.1	17.8
37 1918	104,549,886	30	79,008,412	1,430,079	706,613	575,920	77,694	69,852	18.1	19.3	15.8	26.7	24.4
38 1917	103,413,743	27	70,234,775	981,239	486,208	396,527	52,315	46,189	14.0	14.6	12.4	21.4	19.4
39 1916	101,965,984	26	66,971,177	924,971	461,432	381,165	43,455	38,919	13.8	14.4	12.4	19.9	18.4
40 1915	100,549,013	24	61,894,847	815,500	415,476	346,813	28,452	24,759	13.2	13.7	12.0	20.8	19.5
41 1914	99,117,567	24	60,963,309	810,914	415,493	343,107	28,129	24,185	13.3	13.9	12.1	20.9	19.4
42 1913	97,226,814	23	58,156,740	802,909	413,225	339,040	27,122	23,522	13.8	14.5	12.5	21.0	19.6
43 1912	95,331,300	22	54,847,700	745,771	388,302	321,229	19,791	16,449	13.6	14.3	12.4	21.3	19.7
44 1911	93,867,814	22	53,929,644	749,918	388,238	325,006	19,895	16,779	13.9	14.5	12.8	21.9	20.6
45 1910	92,406,536	20	47,470,437	696,856	365,042	304,433	15,031	12,350	14.7	15.4	13.6	22.3	21.0
46 1909	90,491,525	18	44,223,513	630,057	327,153	276,398	14,398	12,108	14.2	14.9	13.2	22.3	21.2
47 1908	88,708,976	17	38,634,759	567,245	294,173	248,627	13,186	11,259	14.7	15.3	13.6	22.8	22.0
48 1907	87,000,271	15	34,552,837	550,245	286,269	238,990	13,530	11,456	15.9	16.8	14.5	25.0	23.5
49 1906	85,436,556	15	33,782,288	531,005	274,579	231,974	13,112	11,340	15.7	16.5	14.4	24.7	23.6

/1/ Estimates of armed forces overseas are included in the years 1917-19, 1940-54. /2/ Effective 1933, all of continental United States included.

/3/ Exclusive of fetal deaths. For 1940-54, estimates exclusive of deaths among armed forces overseas; rates based on population excluding armed forces overseas. /4/ District of Columbia not included in "Number of States," though represented in all data shown for each year. /5/ Excludes armed forces overseas. /6/ Tentative.

433. AVERAGE REMAINING LIFETIME IN YEARS AT SPECIFIED AGES, BY RACE AND SEX: U.S.A., 1900-1953

For 1900-1902 and 1909-1911, data for the death-registration states of 1900, which consisted of 10 states and the District of Columbia; for 1919-1921, for the death-registration states of 1920, which consisted of 34 states and the District of Columbia; for 1929-1931, 1939-1941, 1949-1951, 1952 and 1953, for the entire continental United States.

and 1922, for the entire Continental United States.																			
Age	1953	1952	1949-1951	1939-1941	1929-1931	1919-1921	1909-1911	1900-1902	Age	1953	1952	1949-1951	1939-1941	1929-1931	1919-1921	1909-1911	1900-1902		
White Male									White Female										
1	0	66.8	66.6	66.3	62.8	59.1	56.3	50.2	48.2	21	0	72.9	72.7	72.0	67.3	62.7	58.5	53.6	51.1
2	1	67.7	67.6	67.4	65.0	62.2	60.2	56.3	54.6	22	1	73.6	73.3	72.8	68.9	64.9	61.5	58.7	56.3
3	5	64.0	64.0	63.8	61.7	59.4	58.3	55.4	54.4	23	5	69.8	69.6	69.1	65.6	62.2	59.4	57.7	56.0
4	10	59.2	59.2	59.0	57.0	55.0	54.2	51.3	50.6	24	10	65.0	64.8	64.3	60.9	57.7	55.2	53.6	52.2
5	15	54.4	54.4	54.2	52.3	50.4	49.7	46.9	46.3	25	15	60.1	59.9	59.4	56.1	53.0	50.7	49.1	47.8
6	20	49.8	49.7	49.5	47.8	46.0	45.6	42.7	42.2	26	20	55.3	55.1	54.6	51.4	48.5	46.5	44.9	43.8
7	25	45.2	45.2	44.9	43.3	41.8	41.6	38.8	38.5	27	25	50.5	50.3	49.8	46.8	44.3	42.6	40.9	40.1
8	30	40.6	40.5	40.3	38.8	37.5	37.7	34.9	34.9	28	30	45.7	45.5	45.0	42.2	40.0	38.7	37.0	36.4
9	35	35.9	35.9	35.7	34.4	33.3	33.7	31.1	31.3	29	35	40.9	40.8	40.3	37.7	35.7	34.9	33.1	32.8
10	40	31.4	31.4	31.2	30.0	29.2	29.9	27.4	27.7	30	40	36.2	36.1	35.6	33.3	31.5	30.9	29.3	29.2
11	45	27.0	27.1	26.9	25.9	25.3	26.0	23.9	24.2	31	45	31.7	31.6	31.1	28.9	27.4	27.0	25.5	25.5
12	50	23.0	23.0	22.8	22.0	21.5	22.2	20.4	20.8	32	50	27.3	27.2	26.8	24.7	23.4	23.1	21.7	21.9
13	55	19.2	19.3	19.1	18.3	18.0	18.6	17.0	17.4	33	55	23.0	23.0	22.6	20.7	19.6	19.4	18.2	18.4
14	60	15.8	15.9	15.8	15.1	14.7	15.3	14.0	14.4	34	60	19.0	19.0	18.6	17.0	16.1	15.9	14.9	15.3
15	65	12.9	13.0	12.8	12.1	11.8	12.2	11.3	11.5	35	65	15.3	15.3	15.0	13.6	12.8	12.8	12.0	12.2
16	70	10.3	10.3	10.1	9.4	9.2	9.5	8.8	9.0	36	70	12.0	12.0	11.7	10.5	10.0	9.9	9.4	9.6
17	75	7.9	8.0	7.8	7.2	7.0	7.3	6.8	6.8	37	75	9.1	9.1	8.9	7.9	7.6	7.6	7.2	7.3
18	80	6.1	6.1	5.9	5.4	5.3	5.5	5.1	5.1	38	80	6.7	6.8	6.6	5.9	5.6	5.7	5.4	5.5
19	85	4.7	4.8	4.4	4.0	4.0	4.1	3.9	3.8	39	85	5.1	5.1	4.8	4.3	4.2	4.2	4.1	4.1
20	90	-	-	3.3	3.1	3.0	3.2	3.0	2.9	40	90	-	-	3.5	3.2	3.2	3.2	3.0	3.0

433. AVERAGE REMAINING LIFETIME IN YEARS AT SPECIFIED AGES, BY RACE AND SEX: U.S.A., 1900-1953 (Concluded)

For 1900-1902 and 1909-1911, data for the death-registration states of 1900, which consisted of 10 states and the District of Columbia; for 1919-1921, for the death-registration states of 1920, which consisted of 34 states and the District of Columbia; for 1929-1931, 1939-1941, 1949-1951, 1952 and 1953, for the entire continental United States.

Age	1953	1952	1949-1951	1939-1941	1929-1931	1919-1921	1909-1911	1900-1902	Age	1953	1952	1949-1951	1939-1941	1929-1931	1919-1921	1909-1911	1900-1902
Non-white Male ¹									Non-white Female ¹ (concluded)								
41	0	59.7	59.1	58.9	52.3	47.6	47.1	34.1	71	45	26.9	26.8	26.1	23.9	21.4	22.6	20.4
42	1	61.7	61.4	61.1	55.9	51.1	51.6	42.5	72	50	23.4	23.2	22.7	21.0	18.6	19.8	17.7
43	5	58.3	58.0	57.7	53.0	48.7	50.2	44.3	73	55	20.3	20.2	19.6	18.4	16.3	17.1	15.0
44	10	53.5	53.3	53.0	48.3	44.3	46.0	40.7	74	60	17.4	17.4	17.0	16.1	14.2	14.7	12.8
45	15	48.8	48.5	48.2	43.7	39.8	41.8	36.8	75	65	14.7	14.8	14.5	13.9	12.2	12.4	10.8
46	20	44.2	44.0	43.7	39.5	36.0	38.4	33.5	76	70	12.9	12.9	12.3	11.8	10.4	10.3	9.2
47	25	39.9	39.7	39.5	35.7	32.7	35.5	30.4	77	75	10.8	10.8	10.2	9.8	8.6	8.4	7.6
48	30	35.7	35.6	35.3	32.1	29.5	32.5	27.3	78	80	9.1	9.1	8.2	8.0	6.9	6.6	6.1
49	35	31.6	31.4	31.2	28.5	26.4	29.5	24.4	79	85	7.6	7.3	6.2	6.4	5.5	5.2	5.1
50	40	27.6	27.5	27.3	25.1	23.4	26.5	21.6	80	90	-	-	4.1	5.0	4.2	4.1	4.5
51	45	23.8	23.8	23.6	21.9	20.6	23.6	18.9	Total Population								
52	50	20.4	20.4	20.3	19.1	17.9	20.5	16.2	81	0	68.8	68.6	68.1	63.6	59.2	56.4	51.5
53	55	17.5	17.5	17.4	16.6	15.5	17.5	13.8	82	1	69.8	69.6	69.2	65.8	61.9	59.9	57.1
54	60	14.9	15.0	14.9	14.4	13.2	14.7	11.7	83	5	66.1	66.0	65.5	62.5	59.3	58.0	56.2
55	65	12.7	12.8	12.8	12.2	10.9	12.1	9.7	84	10	61.3	61.1	60.7	57.8	54.8	53.8	52.2
56	70	11.2	11.1	10.7	10.1	8.8	9.6	8.0	85	15	56.5	56.3	55.9	53.1	50.3	49.4	47.7
57	75	9.5	9.3	8.8	8.2	7.0	7.6	6.6	86	20	51.7	51.6	51.2	48.5	45.9	45.3	43.5
58	80	8.0	8.0	7.1	6.6	5.4	5.8	5.5	87	25	47.1	47.0	46.6	44.1	41.9	41.5	39.6
59	85	6.9	6.8	5.4	5.3	4.3	4.5	4.0	88	30	42.4	42.3	41.9	39.7	37.8	37.7	35.7
60	90	-	-	3.8	4.2	3.4	3.6	4.0	89	35	37.8	37.7	37.3	35.3	33.7	33.9	31.9
Non-white Female ¹									90	40	33.2	33.2	32.8	31.0	29.7	30.1	28.2
61	0	64.4	63.7	62.7	55.6	49.5	46.9	37.7	91	45	28.9	28.8	28.5	26.9	25.8	26.3	24.5
62	1	66.1	65.5	64.4	58.5	52.3	50.4	45.2	92	50	24.7	24.7	24.4	23.0	22.1	22.5	21.0
63	5	62.6	62.1	60.9	55.4	49.8	48.7	46.4	93	55	20.9	20.9	20.6	19.3	18.5	18.9	17.6
64	10	57.8	57.3	56.2	50.8	45.3	44.5	42.8	94	60	17.3	17.3	17.0	15.9	15.2	15.5	14.4
65	15	53.0	52.5	51.4	46.1	40.9	40.4	39.2	95	65	14.0	14.1	13.8	12.8	12.2	12.5	11.6
66	20	48.3	47.8	46.8	42.0	37.2	37.2	36.1	96	70	11.2	11.2	10.9	10.0	9.6	9.7	9.1
67	25	43.7	43.3	42.4	38.2	33.9	34.4	33.0	97	75	8.6	8.6	8.4	7.6	7.3	7.5	7.0
68	30	39.3	38.9	38.0	34.4	30.7	31.5	29.6	98	80	6.6	6.6	6.3	5.7	5.5	5.6	5.3
69	35	35.0	34.7	33.8	30.7	27.5	28.6	27.5	99	85	5.1	5.1	4.7	4.3	4.2	4.2	4.0
70	40	30.9	30.6	29.8	27.2	24.3	25.6	23.3									

/1/ Figures for the non-white groups cover only Negroes, who never comprised less than 95% of the corresponding non-white population.

434. LIFE EXPECTANCY: MAN, VARIOUS NATIONS

Values are years.

values are years.

Nation		Years Upon Which Data Are Based	Expectation of Life at Birth		Nation		Years Upon Which Data Are Based	Expectation of Life at Birth	
			Male	Female				Male	Female
Africa and Adjacent Areas					Europe and Adjacent Areas				
1	Egypt	1936-1938	36.65	41.48	27	Austria	1930-1933	54.50	58.50
2	Mauritius ¹	1942-1946	32.25	33.83	28	Belgium	1946-1949	62.04	67.26
3	S. Rhodesia (Europeans)	1935-1937	58.52	62.57	29	Bulgaria	1925-1928	45.92	46.64
4	Union of South Africa (Europeans)	1945-1947	63.78	68.31	30	Czechoslovakia	1929-1932	51.92	55.18
America, North and Adjacent Areas					31	Denmark	1946-1950	67.80	70.10
5	Barbados	1945-1947	49.17	52.94	32	Finland	1941-1945	54.62	61.14
6	British Honduras	1944-1948	44.99	48.97	33	France	1946-1949	61.90	67.40
7	Canada	1947	65.18	69.05	34	Germany, Federal Republic	1950	64.06	67.92
8	Guatemala	1939-1941	35.97	37.09	35	Greece	1926-1930	49.09	50.89
9	Jamaica	1945-1947	51.25	54.58	36	Hungary	1941	54.92	58.22
10	Mexico	1940	37.92	39.79	37	Iceland	1931-1940	60.90	65.60
11	Panama	1941-1943	50.54	53.46	38	Ireland	1945-1947	60.47	62.43
12	Trinidad and Tobago	1945-1947	52.98	56.03	39	Italy	1930-1932	53.76	56.00 ³
13	United States, White	1951	66.61	72.62	40	Luxembourg	1946-1948	61.69	65.75
14	United States, Non-white	1951	59.37	63.71	41	Malta and Gozo	1946	55.69	57.72
America, South and Adjacent Areas					42	Netherlands	1947-1949	69.40	71.50
15	Brazil	1920	37.43 ²		43	Norway	1945-1948	67.76	71.68
16	British Guiana	1945-1947	49.32	52.05	44	Poland	1948	55.60	62.50
17	Chile	1939-1942	40.65	43.06	45	Portugal	1939-1942	48.58	52.82
18	Venezuela	1941-1942	45.83	47.55	46	Spain	1940	47.12	53.24
Asia and Adjacent Areas					47	Sweden	1941-1945	67.06	69.71
19	Ceylon	1949	54.20	52.80	48	Switzerland	1939-1944	62.68	66.96
20	China (Formosa)	1936-1940	41.08	45.73	49	United Kingdom: England and Wales	1951	65.84	70.88
21	Cyprus	1931-1946	57.30	59.30	50	Northern Ireland	1936-1938	57.80	59.20
22	India	1931-1941	32.09	31.37	51	Scotland	1951	64.20	68.30
23	Israel	1951	67.30	70.10	52	USSR (Europe)	1926-1927	41.93	46.79
24	Japan	1949-1950	56.19	59.61	Oceania				
25	Korea	1938	47.20	50.59	53	Australia	1946-1948	66.07	70.63
26	Thailand, Bangkok	1937-1938	36.73	43.30	54	Hawaii	1919-1920	47.79	47.27
					55	New Zealand (Europeans)	1947	67.77	71.62

/1/ Exclusive of island dependencies. /2/ Total persons. /3/ Value for 1935-1937 was 57.49.

435. AVERAGE LIFE SPAN: MAN, NORTH AMERICA¹

Values are years.

Period	White		Negro		Period	White		Negro	
	Male	Female	Male	Female		Male	Female	Male	Female
1 1850	38.20 ^{2,3}	40.50 ^{2,3}			7 1920-1929 ⁵	57.85	60.62	46.90	47.95
2 1890	42.50 ^{2,3}	44.46 ^{2,3}			8 1929-1931	59.12	62.67	47.55	49.51
3 1900-1902 ⁴	48.23	51.08	32.54	35.04	9 1930-1939 ^{6,7}	60.62	64.52	50.06	52.62
4 1901-1910 ⁴	49.32	52.54	32.57	35.65	10 1939-1941 ⁶	62.81	67.29	52.26	55.56
5 1909-1911 ⁴	50.23	53.62	34.05	37.67	11 1949 ⁶	65.88	71.51	58.57	62.93
6 1919-1921 ⁵	56.34	58.53	47.14	46.92	12 1951 ⁶	66.61	72.62	59.37	63.71

/1/ Increase in life expectancy at birth is mainly caused by decreased infant mortality; expectancy from age 30 was only about 6 years greater in 1949 than in 1850, and expectancy at age 60 was no greater in 1949 than in 1850. /2/ Massachusetts. /3/ Non-whites includes, about 1% of the total. /4/ Original death registration states. /5/ Death registration states in 1920. /6/ Continental United States. /7/ All non-whites.

436. POPULATION, ESTIMATED: VARIOUS WORLD REGIONS
Part I: WORLD POPULATION BY CONTINENTS AND REGIONS
 Values in parentheses are ranges.

Continent and Region		Estimates of Midyear Population, Millions ¹					Area ² sq km x 1000	Population Density, 1953 per sq km
		1920	1930	1940	1950	1953		
1	World total ³	1813 (1753-1872)	1987 (1937-2036)	2213 (2157-2270)	2455 (2370-2540)	2547 (2459-2634)	135,168	19
2								
3	Africa, total	140 (130-151)	155 (145-164)	172 (163-181)	198 (190-207)	208 (199-216)	30,310	7
4								
5	Northern Africa	46 (40-53)	51 (45-56)	57 (52-62)	65 (60-69)	68 (63-72)	10,246	7
6								
7	Tropical and Southern Africa	94 (88-100)	104 (98-110)	115 (110-121)	134 (128-139)	140 (134-146)	20,064	7
8								
9	America, total	208 (204-212)	244 (240-247)	277 (274-280)	330 (326-334)	351 (347-355)	42,097	8
10								
11	North America	117 (115-118)	135 (134-136)	146 (145-147)	160 (167-169)	177 (176-179)	21,482	8
12								
13	Central America	30 (29-31)	34 (33-35)	41 (40-42)	51 (50-52)	55 (54-56)	2760	20
14								
15	South America	61 (59-64)	75 (72-77)	90 (88-92)	111 (108-114)	119 (116-122)	17,855	7
16								
17	Asia, total (except USSR) ⁴	970 (922-1019)	1047 (1007-1087)	1176 (1128-1224)	1321 (1247-1394)	1364 (1288-1439)	27,003	51
18								
19	Southwest Asia	44 (38-50)	48 (43-52)	54 (50-58)	62 (58-66)	66 (61-70)	5543	12
20								
21	South Central Asia	326 (320-333)	362 (355-369)	410 (403-417)	464 (459-470)	482 (476-488)	5143	94
22								
23	Southeast Asia	110 (106-113)	128 (125-132)	155 (151-160)	171 (165-176)	179 (173-186)	4456	40
24								
25	East Asia	490 (449-531)	509 (476-542)	557 (517-597)	624 (558-690)	637 (570-705)	11,861	54
26								
27	Europe, total (except USSR) ⁴	328 (325-330)	355 (353-357)	380 (378-382)	393 (391-395)	402 (400-404)	4930	82
28								
29	Northern and Western Europe	115 (114-116)	122 (122-123)	128 (127-128)	133 (133-134)	136 (135-136)	2252	60
30								
31	Central Europe	112 (111-114)	120 (118-121)	127 (126-129)	128 (127-129)	131 (130-131)	1014	129
32								
33	Southern Europe	101 (99-102)	113 (112-114)	125 (124-126)	131 (130-133)	135 (134-136)	1664	81
34								
35	Oceania	8.8 (8.6-9.1)	10.4 (10.2-10.7)	11.3 (11.1-11.5)	13.0 (12.8-13.2)	14.0 (13.8-14.2)	8557	2
36								

/1/ Estimates include adjustments for under-enumeration of various censuses. /2/ Land area including inland waters but excluding certain uninhabited polar regions and islands. /3/ Including allowance for the population and area of the USSR. /4/ European Turkey is included with Asia.

Part II: ESTIMATES OF TOTAL POPULATION: NORTH AMERICA, 1920-1954

Geographical Area		Estimated Population, Thousands								
		1920	1930	1940	1945	1950	1951	1952	1953	1954
1	Alaska ¹ , total	55	60	75	139	137	161	191	205	
2	Civilian population				74	111	123	141	155	
3	Bahama Islands		61	70	71	79	81	83	85	
4	Barbados		159	168	187	209	212	216		
5	Bermuda ²	22 ³	32	32	35	37	38	39		
6	British Honduras	44 ³	51	56	59	67	70	72	75	
7	Canada ⁴	8820	10,484	11,682	12,394	13,712	14,009	14,430	14,781	15,195
8	Excluding Yukon and N. W. Territories	8543 ⁵	10,195 ⁵	11,364 ⁵	12,055 ⁵	13,688	13,984	14,405	14,756	
9	Newfoundland	264	276	301	322					
10	Yukon and N. W. Territories	13	13	17	17	24	25	25	25	
11	Canal Zone, Panama, total ¹	23	40	57	88	53	56	58	57	
12	Civilian population			31	46	42	42	42	42	
13	Costa Rica	421 ³	499	619	695	800	825	850	881	915
14	Cuba ⁶			4566	4940	5362	5471		5807	
15	Dominican Republic	879	1256	1674	1889	2131	2183	2236	2291	2347
16	El Salvador	1168	1443	1633	1742	1868	1920	1986	2052	2122
17	Greenland ⁷	14	16	19	21	23	23	24	25	
18	Guatemala	1314 ³	1771	2222	2444	2802	2890	2975	3049	
19	Honduras		948	1146	1261	1428	1470	1513	1564	
20	Jamaica	830	997	1183	1266	1403	1430	1457	1486	
21	Cayman Islands		6	7	7	7	7	8		
22	Turks and Caicos Islands		5	6	6	7				
23	Leeward Islands		86	99	107	112	116	119	121	
24	Antigua		30	34	41	45	46	48	49	
25	Montserrat		13	15	15	14	14	13	13	
26	St. Kitts-Nevis and Anguilla		38	43	45	48	49	51	52	
27	Virgin Islands (British)		5	7	6	6	7	7	7	
28	Mexico ⁶		16,589	19,763	22,233	25,791	26,332	26,992	28,053	28,850
29	Netherlands Antilles	55	72	107	131	161	166	172	178	
30	Nicaragua			825	923	1060	1093	1128	1166	1202
31	Panama ⁸	447	471	620	703	797	817	841	863	
32	Puerto Rico ¹	1312	1552	1880	2099	2207	2233	2240	2229	
33	Civilian population			1876	2068	2202	2214	2214	2201	
34	St. Pierre and Miquelon				4		5	5		
35	Trinidad and Tobago		405	476	547	632	649	663	678	698
36	United States ⁹		123,188	132,122	139,928	151,683	154,360	157,022	159,629	162,414
37	Excluding armed forces abroad	106,466	123,077	131,954	132,481	151,234	153,384	155,755	158,306	
38	Virgin Islands (USA) ¹		22	25	27	27	25	24	25	
39	Windward Islands ¹ (Dominica, Grenada, St. Lucia, St. Vincent)			259	263	276	284			
40										

/1/ Legal population, but including U.S. Armed Forces stationed in the area. /2/ Civilian population, excluding tourists. /3/ For 31 December. /4/ Legal population. /5/ Prior to 1950, also excluding Newfoundland, which became the 10th province on 1 April 1949. /6/ Estimates for last intercensal period not yet revised to accord with census results. /7/ Indigenous population, representing approximately 98% of the total. /8/ Excluding Canal Zone shown separately above. /9/ Legal population, but excluding civilian citizens of continental U.S. absent from the country for extended periods of time.

437. POPULATION, PER CENT DISTRIBUTION BY AGE:

Age (yr)	U.S.A., 1850-1950										
	1950	1940	1930	1920	1910	1900	1890	1880	1870	1860	1850
1 <5	10.7	8.0	9.3	10.9	11.6	12.1	12.2	13.8	14.3	15.4	15.1
2 5-9	8.8	8.1	10.3	10.8	10.6	11.7	12.1	12.9	12.5	13.3	14.0
3 10-14	7.4	8.9	9.8	10.1	9.9	10.6	11.2	11.4	12.4	11.8	12.5
4 15-19	7.0	9.4	9.4	8.9	9.9	9.9	10.5	10.0	10.5	10.7	10.9
5 20-24	7.6	8.8	8.9	8.8	9.8	9.7	9.9	10.1	9.7	18.2	18.4
6 25-29	8.1	8.4	8.0	8.6	8.9	8.6	8.3	8.1	8.0	12.8	12.2
7 30-34	7.6	7.8	7.4	7.6	7.6	7.3	7.3	6.7	6.6	12.8	12.2
8 35-39	7.5	7.2	7.5	7.4	7.0	6.5	6.2	6.0	6.0	8.3	8.0
9 40-44	6.8	6.7	6.5	6.0	5.7	5.6	5.1	4.9	5.0	5.0	4.8
10 45-49	6.0	6.3	5.7	5.5	4.9	4.5	4.4	4.2	4.1	5.0	4.8
11 50-54	5.5	5.5	4.9	4.5	4.2	3.9	3.7	3.7	3.5	2.8	2.6
12 55-59	4.8	4.4	3.8	3.4	3.0	2.9	2.7	2.5	2.3	2.2	2.0
13 60-64	4.0	3.6	3.1	2.8	2.5	2.4	2.3	2.2	2.0	1.4	1.3
14 65-69	3.3	2.9	2.3	2.0	1.8	1.7	1.6	1.4	1.3	1.1	1.0
15 70-74	2.3	2.0	1.6	1.3	1.2	1.2	1.1	1.0	0.9	1.4	1.5
16 >74	2.6	2.0	1.6	1.4	1.3	1.2	1.1	1.0	0.8	0.2	0.1
17 Not reported			0.1	0.1	0.2	0.3	0.3				

438. POPULATION, MALE-FEMALE RATIO: U.S.A., 1790-1950

Census Year	Values are number of males per 100 females.			
	All Classes	White	Negro	Other Races
1 1950	98.6	99	94.3	131.7
2 1940	100.7	101.2	95	140.5
3 1930	102.5	102.9	97	150.6
4 1920	104	104.4	99.2	156.6
5 1910	106	106.6	98.9	185.7
6 1900	104.4	104.9	98.6	185.2
7 1890	105	105.4	99.5	182.5
8 1880	103.6	104	97.8	362.2
9 1870	102.2	102.8	96.2	400.7?
10 1860	104.7	105.3	99.6	260.8
11 1850	104.3	105.2	99.1	
12 1840	103.7	104.5	99.5	
13 1830	103.1	103.8	100.3	
14 1820	103.3	103.2	103.4	
15 1810		104		
16 1800		104		
17 1790		103.8		

439. POPULATION, LIVE BIRTHS AND BIRTH RATES, BY RACE: U.S.A., 1915-1954

Population estimated as of July 1 for 1916-1939, 1942-48 and 1952, and enumerated as of April 1 for 1940 and 1950. Rates are per 1000 population in each specified group.

Year	Population of Continental United States ¹	Number of States ⁴	Population ⁵	Birth Registration States ²			Births Adjusted for Under-registration ³			United States ⁶	
				Registered Births			Birth Rates ⁵			Number	
				Total			White			Rates ⁶	
				Total	White	Non-white	Total	White	Non-white	White	Non-white
1 1954	162,414,000	48	161,195,000	4,021,000	3,356,772	545,348	24.9	23.7	32.3	3,389,000	575,000
2 1953 ⁸	159,629,000	48	158,306,000	3,902,120	3,322,658	524,328	24.8	23.9	31.8	3,358,000	555,000
3 1952 ⁸	157,022,000	48	155,755,000	3,846,986	3,237,072	513,778	24.7	23.6	31.8	3,277,000	546,000
4 1951 ⁸	154,360,000	48	153,384,000	3,750,850	3,163,627	490,522	24.5	23.6	31.1	3,108,000	524,000
5 1950	151,132,000	48	150,697,361	3,554,149	3,083,721	475,808	23.6	22.7	30.6	3,136,000	513,000
6 1949	149,188,000	48	148,665,000	3,559,529	3,080,316	454,752	23.9	23.2	29.8	3,141,000	495,000
7 1948	146,631,000	48	146,093,000	3,535,068	3,080,316	454,752	24.2	23.5	28.3	3,347,000	469,000
8 1947	144,126,000	48	143,446,000	3,699,940	3,274,620	425,320	25.8	25.5	25.3	2,990,000	420,000
9 1946	141,389,000	48	141,389,000	3,228,672	2,913,645	375,027	25.3	23.0	23.2	2,471,000	388,000
10 1945	139,928,000	48	139,928,000	2,735,456	2,395,563	339,893	19.5	19.1	23.6	2,545,000	394,000
11 1944	138,397,000	48	138,397,000	2,794,800	2,454,700	340,100	20.2	19.8	24.1	2,704,000	400,000
12 1943	136,739,000	48	136,739,000	2,934,860	2,486,934	342,062	21.5	21.2	23.2	2,605,000	384,000
13 1942	134,860,000	48	134,860,000	2,808,996	2,204,903	308,524	20.8	20.6	22.6	2,330,000	374,000
14 1941	133,402,000	48	133,402,000	2,513,427	2,067,953	292,466	18.8	18.4	21.7	2,199,000	360,000
15 1940	131,820,000	48	131,820,000	2,360,399	1,982,671	282,917	17.9	17.5	21.2	2,177,000	349,000
16 1939	130,879,718	48	130,879,718	2,265,588	1,867,245	245,515	17.3	16.9	21.0	2,170,000	335,000
17 1938	129,824,939	48	129,824,939	2,286,962	1,867,245	245,515	17.6	17.2	21.0	2,170,000	335,000
18 1937	128,824,829	48	128,824,829	2,203,337	1,928,437	274,900	17.1	16.7	20.9	2,071,000	342,000
19 1936	128,053,180	48	128,053,180	2,144,790	1,881,883	262,907	16.7	16.4	20.6	2,042,000	334,000
20 1935	127,250,232	48	127,250,232	2,155,105	1,888,012	267,093	16.9	16.5	20.9	2,058,000	338,000
21 1934	126,373,773	48	126,373,773	2,167,636	1,898,501	269,135	17.2	16.7	20.2	1,982,000	325,000
22 1933	125,578,763	48	125,578,763	2,081,232	1,823,531	257,701	16.6	16.2	21.3	2,099,000	341,000
23 1932	124,840,471	47	118,903,899	2,074,042	1,822,425	251,617	17.4	17.0	21.0	2,170,000	335,000
24 1931	124,039,648	46	117,455,229	2,112,760	1,867,245	245,515	18.0	17.7	21.6	2,274,000	344,000
25 1930	123,076,741	46	116,544,946	2,203,958	1,953,163	250,795	18.9	18.6	21.3	2,244,000	339,000
26 1929	121,769,939	46	115,317,450	2,169,920	1,924,475	245,445	18.8	18.5	22.1	2,325,000	349,000
27 1928	120,501,115	44	113,636,160	2,233,149	1,982,246	250,903	19.7	19.4	23.6	2,425,000	377,000
28 1927	119,038,062	40	104,320,830	2,137,836	1,925,585	212,251	20.5	20.2	25.0	2,441,000	398,000
29 1926	117,399,225	35	90,400,590	1,856,068	1,707,034	149,034	20.5	20.2	25.4	2,506,000	403,000
30 1925	115,831,963	33	88,294,564	1,878,880	1,731,669	147,211	21.3	21.0	26.3	2,577,000	401,000
31 1924	114,113,463	33	87,000,295	1,930,614	1,762,872	167,742	22.2	21.9	25.3	2,531,000	380,000
32 1923	111,949,945	30	81,072,123	1,792,646	1,644,034	148,612	22.1	21.9	25.3	2,507,000	375,000
33 1922	110,054,778	30	79,560,746	1,774,911	1,629,387	145,524	22.3	22.1	27.6	2,657,000	398,000
34 1921	108,541,489	27	70,807,090	1,714,261	1,565,446	148,815	24.2	23.9	27.0	2,566,000	383,000
35 1920	106,466,420	23	63,597,307	1,508,874	1,395,523	113,351	23.7	23.5	24.9	2,387,000	353,000
36 1919	105,062,747	22	61,212,076	1,373,438	1,269,363	104,075	22.4	22.3	24.8	2,588,000	360,000
37 1918	104,549,886	20	55,153,782	1,363,649	1,288,711	74,938	24.7	24.8	24.3	2,587,000	357,000
38 1917	103,413,743	20	55,197,952	1,353,792	1,280,288	73,504	24.5	24.5	24.3		
39 1916	101,965,984	11	32,994,013	818,983			24.9				
40 1915	100,549,013	10	31,096,697	776,304			25.0				

/1/ Estimates of armed forces overseas are included in the years 1918, 1940-1954. /2/ Effective 1934, all of continental United States included. /3/ Adjustments on the basis of 48 states for lines 12 through 20. /4/ District of Columbia not included in the "Number of States," though represented in all data shown for each year. /5/ For 1942-46, estimates of population include armed forces overseas; rates based on population, including armed forces overseas. /6/ For 1917-19 and 1941-46 based on population including armed forces overseas. /7/ Tentative. /8/ Based on births from a 50% sample.

440. SEX RATIOS: ANIMALS

Values are males per 100 individuals. Values in parentheses are estimates "b" of the 95% range, unless otherwise indicated by superscripts (cf Introduction). Adult values should be considered with caution (particularly those for Invertebrates) because of extreme variation caused by geographical area, species considered, time of year, and population conditions.

Species		At Birth	Adult	Species		At Birth	Adult
Mammalia				Aves (concluded)			
1	Man, white, U.S.A. ¹	51.39		70	Crow (<i>Corvus brachyrhynchos</i>)		56
2	Man, non-white, U.S.A. ¹	50.28		71	Dove (<i>Zenaidura macroura</i>)	52(50-54)	60(57-63)
3	Ass (<i>Equus asinus</i>)	49(32-66)		72	Duck (<i>Anas</i> spp)	50(49-52)	
4	Badger (<i>Meles meles</i>)		54(34-75)	73	Canvasback	51(47-55) ^d	
5	Bat, big brown (<i>Eptesicus fuscus</i>)		68(32-78) ^d	74	Mallard	53(49-57) ^d	52(48-56) ^d
6	Bat (<i>Myotis sodalis</i>)		51(49-53)	75	Pintail	53(49-57) ^d	66(64-69) ^d
7	Bat (<i>Pipistrellus subflavus</i>)		74(68-80)	76	Redhead	53(48-58) ^d	
8	Beaver (<i>Castor canadensis</i>)		52(45-59)	77	Fowl (<i>Gallus</i> spp)	49(47-51) ^d	
	Cattle (<i>Bos taurus</i>)			78	Rhode Island Red	50(46-54)	
9	Single birth	52(43-58) ^d		79	White Leghorn	49(48-51)	
10	Twin birth	49		80	Grackle (<i>Quiscalus</i> spp)		30(26-35) ^d
11	Triplet birth	46		81	Grouse, ruffed (<i>Bonasa</i> sp)	52(47-56) ^d	52(42-61) ^d
12	Ayrshire	49(45-53)		82	Grouse, sage		50(48-52) ^d
13	Brown alpine	50(47-52)		83	Grouse, sharp-tailed		63(54-72) ^d
14	Guernsey	44(41-48)		84	Hawk (<i>Buteo</i> spp)		50(46-54)
15	Hereford	51(49-53)		85	Parrot (<i>Psittacus</i> spp)		57(50-63)
16	Holstein	49(47-50)		86	Partridge (<i>Perdix</i> spp)	43(38-48) ^d	60(58-62) ^d
17	Jersey	52(48-56)		87	Pheasant, ring-necked (<i>Phasianus</i> sp)	50(46-54) ^d	52(50-55)
18	Shorthorn	49(47-51)		88	Pigeon (<i>Columba</i> spp)	50(48-52) ^d	
19	Welsh, black	50(48-52)		89	Quail, bobwhite (<i>Colinus</i> sp)		(59-66)
20	Zebu	51(50-52)		90	Quail, California (<i>Lophortyx</i> sp)		58(54-62) ^d
	Dog (<i>Canis familiaris</i>)			91	Redwing (<i>Agelaius</i> sp)		77(73-81)
21	Collie, St. Bernard, spaniel	54(53-55)		92	Sparrow (<i>Melospiza melodia</i>)		52
22	German shepherd	55(51-58) ^d		93	Starling (<i>Sturnus</i> spp)		68
23	Greyhound	52(51-54)		94	Turkey (<i>Meleagris gallopavo</i>)		50(48-55)
24	Schnauzer	51(49-53)		Reptilia			
25	Terrier	56(53-59)		95	Lizards		58(55-62)
26	Elk, North American	51(46-56) ^d		96	Snakes		50(48-52)
27	Fox, red	50(41-59)	52(46-56) ^d	97	Tortoises, turtles		43(38-48)
28	Fox, silver	53(51-55)		Amphibia			
29	Goat, Angora	50(48-52) ^d		98	Frogs, toads		45(43-47)
30	Goat, crossbreeds	51(48-54)		99	Salamanders, newts		56(51-61)
31	Goat, Saanen (Britain)	55(50-61)		Pisces			
32	Goat, Toggenburg	50(46-55)		100	Elasmobranchs		47(45-48)
33	Guinea pig (<i>Cavia porcellus</i>)	52(51-53) ^d		101	Sturgeons and spoonbills		17(8-26)
34	Hare (<i>Lepus americanus</i>)		54(52-56)		True bony fishes		
35	Horse (<i>Equus caballus</i>)	52(50-55) ^d		102	Minnow (<i>Gambusia holbrooki</i>)	50(48-53)	
36	Horse, Thoroughbred	50		103	Walleye (<i>Stezostedion vitreum</i>)		72
37	Mink, ranch (<i>Mustela</i> spp)	51(49-53) ^d		Arthropoda			
38	Mink, hybrid, pastel	50(48-52)		Crustacea			
39	Mole (<i>Scalopus aquaticus</i>)		58(55-60)	104	Amphipoda		38(35-40)
40	Mouse (<i>Mus musculus</i>)		52(50-54) ^d	105	Cladocera		20(18-22)
41	Mouse, albino	50(48-52) ^d		106	Copepoda		28(27-29)
42	Mouse, Japanese and waltzing	51(48-52) ^d		107	Cumacea		37(29-45)
43	Mule	44(42-47) ^d		108	Decapoda		55
44	Muskrat (<i>Ondatra zibethica</i>)	54(42-66) ^d	56(55-57) ^d	109	Isopoda		33(31-35)
45	Opossum (<i>Didelphis marsupialis</i>)	57	57(50-68) ^d	110	Myriopoda		31(28-33)
46	Rabbit (<i>Oryctolagus</i> spp)	50(49-51) ^d		111	Ostracoda		39(35-43)
47	Rabbit, Flemish giant	57(46-68) ^d		112	Phyllopoda		28(27-29)
48	Rabbit, Polish	51(45-56) ^d		113	Stomatopoda		44(36-52)
49	Raccoon (<i>Procyon lotor</i>)		52(46-58) ^d	114	Xiphura		49(32-66)
50	Rat (<i>Rattus norvegicus</i>)	50(49-51) ^d		Insecta			
51	Rat, albino	50(49-51)		115	Anoplura and Mallophaga		(40-50) ^d
52	Rat, brown	51(48-55)	41(40-42) ^d	116	Coleoptera		77
53	Rat, hybrid and piebald	51(50-52)		117	Diptera		43(42-45)
54	Seal, harbor (<i>Phoca groenlandica</i>)		51(48-54)	118	Diptera (<i>Drosophila melanogaster</i>)		46
	Sheep (<i>Ovis aries</i>)			119	Hemiptera		12(11-13)
55	Single birth	50(44-55) ^d		120	Lepidoptera		53(52-54)
56	Twin and triplet birth	49		121	Odonata		77(74-81)
57	Quadruplet birth	43		122	Orthoptera		44(43-45)
58	Cheviot	49(48-50)		123	Strepsiptera		65(62-68)
59	Karakul	52(47-57)		124	Thysanoptera		12(10-13)
60	Merino	47(44-50)		125	Thysanura		64(46-82)
61	Navajo	49(48-50)		126	Arachnida		48(46-49)
62	Swine (<i>Sus scrofa</i>)	52(51-53) ^d		127	Pycnogonida		36(35-38)
63	Berkshire	51(50-52)		Mollusca			
64	Duroc, Jersey	49(48-50)		128	Cephalopoda		46(43-49)
65	German improved	51(50-52) ^d		129	Gastropoda		47(46-48)
66	Inbred and linecross non-inbred	52(51-53)		130	Pelecypoda		50(49-51)
67	Weasel (<i>Mustela nivalis</i>)		73(63-83)	Trochelmithes			
Aves				131	Rotifera		33(32-34)
68	Canary (<i>Serinus</i> spp)	44(36-51) ^d		Coelenterata			
69	Cuckoo (<i>Cuculus</i> sp)		55(52-58)	132	Placophora		53(52-54)

/1/ Values based on 50% sample of 1952 registered live births.

441. ACREAGE AND YIELD, FIELD, FRUIT, AND VEGETABLE CROPS: U.S.A.

Part I: FIELD CROPS

Where plant part or product is specified, acreage values apply to the plants grown for the yield of that part or product.

Crop Plant	Acreage Harvested				Yield per Acre			
	1930-1939 ¹	1940-1949 ¹	1950	1953	1930-1939 ¹	1940-1949 ¹	1950	1953
	Thousands of Acres ²				Pounds ³			
1 Alfalfa (<i>Medicago sativa</i>), seed	556	881	927	939	112	92	113	145
2 Barley (<i>Hordeum vulgare</i>), grain	10,707	12,569	11,153	8534	989	1172	1306	1354
3 Bean, edible (<i>Phaseolus</i> spp) ⁴	1716	1882	1512	1398	781 ⁵	958 ⁵	1117 ⁵	1296 ⁵
4 Beet, sugar (<i>Beta vulgaris</i>)	815	750	925	745	2280	26,200	29,200	32,400
5 Buckwheat (<i>Fagopyrum esculentum</i>), grain	460	405	253	175	800	870	840	874
6 Clover, alsike (<i>Trifolium hybridum</i>), seed	172	132	96	63	119	153	146	192
7 Clover, red (<i>T. pratense</i>), seed	947	1755	2556	1415	70	56	58	59
8 Corn, all (<i>Zea mays</i>)	98,049	87,882	81,817	80,279	1316 ⁵	1898 ⁵	2094 ⁵	2218 ⁵
9 Cotton (<i>Gossypium</i> spp), lint	31,223	21,662	17,843	24,340	205	266	269	324
10 Cowpea (<i>Vigna</i> spp), peas	1140	854	420	318	384 ⁵	342 ⁵	390 ⁵	372 ⁵
11 Flaxseed (<i>Linum</i> spp)	1788	3919	4090	4380	358	526	549	470
12 Hay, all types	67,893	74,845	74,368	73,918	2320	2720	2760	2840
13 Hop (<i>Humulus</i> spp), grain	30	37	39	28	1171	1267	1508	1488
14 Lespedeza (<i>Lespedeza</i> spp), seed	361	885	746	445	173	216	192	143
15 Oat (<i>Avena sativa</i>), grain	36,487	39,460	40,733	39,358	874	1062	1107	989
16 Peanut (<i>Arachis hypogaea</i>)	1486	2923	2268	1541	714 ⁶	704 ⁶	898 ⁶	1031 ⁶
17 Pea, field (<i>Pisum sativum</i>)	261	471	233	262	1008 ⁵	1230 ⁵	1376 ⁵	1279 ⁵
18 Rice (<i>Oryza sativa</i>), rough	942	1507	1620	2135	2178	2083	2388	2460
19 Rye (<i>Secale cereale</i>), grain	3320	2448	1744	1382	627	683	683	728
20 Sorghum (<i>Sorghum</i> spp), grain	7564	6737	10,335	6137	553	875	1266	997
21 Soybean (<i>Glycine soja</i>), bean	2052	9348	13,814	14,366	966 ⁵	1140 ⁵	1302 ⁵	1098 ⁵
22 Sugar cane (<i>Saccharum officinarum</i>), sirup	137	108	49	27	1809	1975	2134	2372
23 Sugar cane (<i>S. officinarum</i>), sugar	257	306	333	346	36,000	38,800	41,600	44,200
24 Sweetclover (<i>Melilotus alba</i>), seed	279	258	547	226	185	161	156	151
25 Timothy (<i>Phleum pratense</i>), seed	483	354	445	197	149	158	142	134
26 Tobacco (<i>Nicotiana tabacum</i>), leaves	1676	1613	1599	1634	834 ⁷	1100 ⁷	1269 ⁷	1259 ⁷
27 Velvetbean (<i>Stizolobium</i> spp)	1970	1486	580	311	806 ⁸	824 ⁸	890 ⁸	823 ⁸
28 Wheat, all (<i>Triticum aestivum</i>), grain	55,883	62,625	61,610	67,608	798	1026	990	1050
29 Wheat, winter (<i>T. aestivum</i>), grain	39,141	44,640	43,253	46,681	864	1,062	1,026	1128

/1/ Data applicable to 10-year averages. /2/ Acres x 0.4047 = hectares. /3/ Pounds per acre x 1.121 = kg per hectare. /4/ Besides the ordinary edible beans (kidney and lima) and beans grown for seed, data include blackeyes and garbanzos in California. /5/ Shelled. /6/ Picked and threshed. /7/ Farm sales-weight basis. /8/ Not shelled.

Part II: FRUIT AND VEGETABLE CROPS

Crop Plant	Acreage Harvested				Yield per Acre			
	1930-1939 ¹	1940-1949 ¹	1950	1953	1930-1939 ¹	1940-1949 ¹	1950	1953
	Thousands of Acres ²				Thousands of Pounds ³			
1 Apple (<i>Pyrus malus</i>) ⁴	1252 ⁵	884	817		5.6 ⁵	5.9	7.2	
2 Asparagus (<i>Asparagus officinalis</i>)	112	127	131	135	2.2	2.5	2.5	2.2
3 Avocado (<i>Prunus gratissima</i>)	9.5	15.3 ⁶			1.5	2.4 ⁶		
4 Bean, lima (<i>Phaseolus lunatus macrocarpus</i>) ⁷	49	88	120	128	2.2 ⁸	2.5 ⁸	3.2 ⁸	3.7 ⁸
5 Bean, string (<i>P. vulgaris</i>) ⁹	213	293	306	296	2.7	3.1	3.5	3.8
6 Beet, garden (<i>Beta vulgaris</i>)	19	28	30	25	10.4 ¹⁰	13.3 ¹⁰	15.3 ¹⁰	15.9 ¹⁰
7 Cabbage (<i>Brassica oleracea capitata</i>)	176	192	186	169	13.3	14.6	17.5	17.1
8 Cantaloupe (<i>Cucumis melo</i>) ¹¹	108	109	134	141	6.7	6.9	7.6	7.8
9 Carrot (<i>Daucus carota</i>)	42	73	94	82	15.8 ¹⁰	16.8 ¹⁰	17 ¹⁰	19 ¹⁰
10 Cauliflower (<i>Brassica oleracea botrytis</i>) ¹²	30	35	33	30	9.6	11.3	13.8	15.8
11 Celery (<i>Apium graveolens</i>)	37	41	36	37	26	31	37.2	39.1
12 Cherry (<i>Prunus</i> spp)	101	107 ⁶	29	26	2.8	3.3 ⁶		
13 Corn, sweet (<i>Zea mays saccharata</i>) ¹³	319	465	557	718	4.2 ¹⁴	4.9 ¹⁴	5.5 ¹⁴	5.9 ¹⁴
14 Cucumber (<i>Cucumis sativus</i>)	127	160	158	200	3.7	4.2	4.2	5.1
15 Fig (<i>Ficus carica</i>), from California	42	35	29	26	3.8	6.7	5.8	6.5
16 Grape (<i>Vitis</i> spp)	680	627 ⁶			6.6	8.8 ⁶		
17 Grapefruit (<i>Citrus paradisi</i>)	154	193	175	146	12.3	20.6	21.2	26.5
18 Lemon (<i>C. limonia</i>), from California	43	61	54	55	15.6	16.7	19.5	22.8
19 Lettuce (<i>Lactuca sativa</i>)	159	173	227	210	8.8	11.6	11.7	13.4
20 Onion (<i>Allium cepa</i>)	128	130	136	132	11.9	14.6	16.9	18.7
21 Orange (<i>Citrus</i> spp)	426	539	562	564	10.5	15.3	18.7	20
22 Pea, garden (<i>Pisum sativum</i>) ⁷	370	476	442	443	3.2 ⁸	5.2 ⁸	5.1 ⁸	5.3 ⁸
23 Peach (<i>Prunus persica</i>)	639	646 ⁶			4.2	5.2 ⁶		
24 Pear (<i>Pyrus communis</i>)	220	178 ⁶			6.1	8.4 ⁶		
25 Potato (<i>Solanum tuberosum</i>)	3238	2515	1696	1508	6.8	10.1	15.2	14.9
26 Prune (<i>Prunus domestica</i>)	224	183 ⁶			6.2	6.6 ⁶		
27 Spinach (<i>Spinacia oleracea</i>)	79	99	81	69	4.0	4.1	5.1	6.1
28 Strawberry (<i>Fragaria</i> spp)	170	121	127	112	2.3	2.6	3.1	4.0
29 Sweetpotato (<i>Ipomoea batatas</i>)	845	641	492	350	4.6	5.0	5.6	5.3
30 Tomato (<i>Lycopersicon esculentum</i>)	562	739	581	528	7.5	10.0	12.1	15.7
31 Watermelon (<i>Citrullus vulgaris</i>)	256	250	374	435	6.7	7.2	6.4	6.2

/1/ Data applicable to 10-year averages, unless otherwise specified. /2/ Acres x 0.4047 = hectares. /3/ Pounds per acre x 1.121 = kg per hectare. /4/ Commercial orchards only. /5/ Average for 1934-1939. /6/ Average for 1940-1946. /7/ Immature seeds. /8/ Not shelled. /9/ Immature edible pods. /10/ Without tops. /11/ Data include Casaba and Persian melons but not honey balls and honey dews. /12/ Data include headed types. /13/ Commercial crops used for processing. /14/ In husk.

442. SPECIFIED NOTIFIABLE DISEASES, REPORTED CASES AND DEATHS: U.S.A., 1945-1954

Data for 1949-1954 classified according to the Sixth Revision of the International List (1948); for 1945-1948 data classified according to the Fifth Revision of the International List (1938).

(-) = data not available.

Disease		1954	1953	1952	1951	1950	1949	1948	1947	1946	1945
1 Amebiasis	Cases	3523	4444	4280	3550	4568	5543	4871	3365	4093	3412
2	Deaths	131	129	136	148	136	164	113	155	182	185
3 Anthrax	Cases	22	45	47	60	49	54	60	69	40	40
4	Deaths	0	0	3	3	5	0	5	3	7	6
5 Botulism	Cases	18	18	18	33	20	24	39	44	(-)	(-)
6	Deaths	14	17	14	31	16	22	(-)	(-)	(-)	(-)
7 Brucellosis (undulant fever)	Cases	1823	2032	2537	3139	3510	4235	4991	6321	5887	5049
8	Deaths	15	18	23	34	36	68	55	58	69	94
9 Dengue	Cases	6	8	5	16	26	46	24	35	40	106
10	Deaths	0	0	0	0	0	2	0	0	1	0
11 Diphtheria	Cases	2041	2355	2960	3983	5796	7969	9493	12,262	16,354	18,675
12	Deaths	145	156	217	302	410	574	634	799	1259	1598
13 Dysentery, bacillary (shigellosis)	Cases	13,846	16,533	23,197	32,215	23,367	29,080	23,753	17,048	24,286	34,943
14	Deaths	243	337	334	356	335	498	364	273	309	506
15 Encephalitis, acute infectious	Cases	2,606	1935	1912	1123	1135	903	730	785	728	785
16	Deaths	407	386	471	429	394	465	570	630	642	735
17 Hepatitis, infectious and serum	Cases	50,093	33,700	17,428	7349	2820	2027	709	1092	(-)	(-)
18	Deaths	821	821	794	675	552	560	(-)	(-)	(-)	(-)
19 Leprosy	Cases	56	60	57	57	44	41	63	56	43	40
20	Deaths	4	7	4	3	3	4	21	16	16	27
21 Leptospirosis	Cases	48	42	62	13	30	21	18	15	(-)	(-)
22	Deaths	14	17	12	13	16	21	13	15	13	31
23 Malaria	Cases	715	1310	7023	5600	2184	4151	9606	15,116	48,610	62,763
24	Deaths	24	32	25	64	76	118	170	214	341	443
25 Measles	Cases	682,720	449,146	683,077	530,118	319,124	625,281	615,104	222,375	695,843	146,013
26	Deaths	518	462	618	683	468	949	888	472	1310	307
27 Meningococcal infections	Cases	4436	5077	4884	4164	3788	3519	3376	3420	5693	8208
28	Deaths	1015	1325	1386	1124	974	917	873	917	1257	1728
29 Plague	Cases	0	0	0	1	3	3	0	1	0	0
30	Deaths	0	0	0	0	1	1	0	1	0	0
31 Poliomyelitis, acute	Cases	38,476	35,592	57,879	28,386	33,300	42,033	27,726	10,827	25,698	13,624
32	Deaths	1368	1450	3145	1551	1904	2720	1895	580	1845	1186
33 Psittacosis and ornithosis	Cases	563	169	135	25	26	35	32	27	26	27
34	Deaths	3	4	5	1	0	0	0	1	2	0
35 Q fever	Cases	8	4	7	8	0	2	1	0	(-)	(-)
36	Deaths	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)	(-)
37 Rabies in man ¹	Cases	13	12	24	18	18	10	24	26	34	43
38	Deaths	13	12	24	18	18	10	24	26	34	43
39 Rabies in animals ²	Cases	7297	8903	8445	8008	7901	7587	8495	8920	10,850	9928
40	Deaths	(-)	8903	8445	8008	7901	7587	8495	8920	10,850	9928
41 Rocky Mountain spotted fever	Cases	294	313	327	347	464	570	547	596	587	472
42	Deaths	10	21	20	26	31	36	94	105	124	128
43 Salmonellosis, paratyphoid fever	Cases	5375	3946	2596	1773	1233	1243	882	951	723	649
44	Deaths	48	72	42	31	43	37				
45 Scarlet fever and streptococcal	Cases	147,785	132,935	113,677	84,151	64,494	87,220	91,295	93,595	125,511	185,570
46 sore throat	Deaths	262	295	351	347	346	486	460	514	754	1094
47 Smallpox	Cases	9 ³	4	21	11	39	49	57	176	337	346
48	Deaths	0	1	0	1	1	2	5	5	25	12
49 Tetanus	Cases	524	506	484	506	486	579	601	560	(-)	(-)
50	Deaths	332	337	360	394	336	398	506	511	585	653
51 Trachoma	Cases	1172	773	3088	2916	1584	1475	2565	1540	(-)	(-)
52	Deaths	1	0	0	0	0	0	(-)	(-)	(-)	(-)
53 Trichiniasis	Cases	277	395	367	393	327	353	487	451	(-)	(-)
54	Deaths	1	7	10	10	9	9	15	14	16	20
55 Tuberculosis, all forms	Cases	100,589	106,925	109,837	118,491	121,742	134,865	137,006	134,946	119,256	114,931
56	Deaths	16,392	19,544	24,621	30,863	33,959	39,100	43,833	48,064	50,911	52,916
57 Tularemia	Cases	681	601	668	702	927	1179	1086	1401	1355	900
58	Deaths	4	7	8	9	15	18	46	58	113	122
59 Typhoid fever	Cases	2169	2252	2341	2128	2484	2795	2840	3075	3268	4211
60	Deaths	45	52	78	83	96	161	205	282	349	471
61 Typhus fever, endemic (murine)	Cases	163	221	205	378	685	985	1171	2050	3365	5193
62	Deaths	0	0	0	0	0	2	68	88	128	173
Venereal diseases ⁴											
63 Gonorrhea	Cases	249,883	246,311	253,839	254,057	286,746	317,950	345,501	380,666	415,855	313,363
64	Deaths	15	29	45	43	37	66	71	108	150	212
65 Syphilis	Cases	131,260	150,026	169,198	174,924	217,558	256,463	314,313	355,592	385,524	351,767
66	Deaths	4835	5273	5719	6274	7568	8581	11,616	12,671	12,955	14,062
67 Other specified venereal	Cases	4650	5209	6093	6885	8187	11,034	12,559	14,371	13,461	10,261
68 diseases	Deaths	29	36	38	42	43	50	47	68	83	84
69 Whooping cough (pertussis)	Cases	60,886	37,129	45,030	68,687	120,718	69,479	74,715	156,517	109,860	133,792
70	Deaths	373	270	402	951	1118	727	1146	1954	1241	1752

/1/ For 1945-53, figures represent registered deaths. /2/ For 1945-51, figures from the Animal Disease and Parasite Research Branch, Agricultural Research Service, U. S. Department of Agriculture. /3/ None of these cases fulfill the criteria for a diagnosis of smallpox.

/4/ For 1945-51, figures (civilian cases only) from the Division of Venereal Diseases, U. S. Public Health Service.

443. DISPERSION OF SMALL ORGANISMS

Disease, Organism [Means of Dispersion]		Distances and Units Dispersed				Disease, Organism [Means of Dispersion]		Distances and Units Dispersed			
Plant Diseases						Insects (concluded)					
1 Celery mosaic [insects]	Ft from harbored plant	3	28	120	225	59 Curculio, plum (Conotrachelus nenuphar) [flight]	Ft from release point	50	136	335	670
	Diseased plants, %	100	52	16	0		Insects recovered, no.	48	13	2	1
2 Chestnut blight (Endothia parasitica) [air currents]	Ft from spore source	27	85	180	265	60 Earworm, corn (Heliothis armigera) [flight] convergence	Rows from light traps	1	3	5	10
	Ascospores, no.	23	11	8	8		Plants infested, %	32.4	31.9	31.6	31.3
3 Citrus psorosis [unknown]	Tree spaces from source		1	2	3	61 Fly, apple maggot (Rhagoletis pomonella) [flight]	Ft from release point		37.5	137.5	237.5
	Diseased trees, %		32	20	14		Flies recovered, no.		47	26	17
4 Cucurbit mosaic, cucumber [insects]	Yd from harbored plant	1	225	350	500	62 Fly, Hessian (Phytophaga destructor) [flight]	Ft from hibernation	7.5	27.5	47.5	97.5
	Days to 1st symptoms	17	45	47	49		Plants infested, %	44	16	9	3
5 Curley top, sugar beet [beet leafhopper]	Mi. from breeding ground		57	315	430	63 Fly, Hessian (P. destructor) [flight]	Ft from wheat field		100	400	600
	Diseased plants, %		100	10	1		Flies caught, no.		95	16	12
6 Dutch elm disease (Ceratostomella ulmi) [beetle]	Ft from inoculum source	12.5	300	575		64 Fly, house (Musca domestica) [flight]	Yd from release point		150	450	1050
	Diseased trees, no.		27	11	8		Flies caught, no./trap/da		3.6	1.2	0.8
7 Downy mildew (Pseudoperonospora humilis) [air currents]	Ft from spore source	10	100	200	400	65 Fly, narcissus bulb (Merodon equestris) [flight]	Ft from old planting	7	85	200	300
	Leaves infected, %	26	12	7	3		Plants infested, %	42	21	13	10
8 Onion mildew (Peronospora destructor) [air currents]	Ft from onion sets		120	780	2000	66 Fly, tsetse (Glossina morsitans) [flight]	Yd, following man	50	1000	4000	6000
	Lesions/100 ft row, no.		1100	100	0		Flies, no.	30	13	5	3
9 Potato calico [insects]	Rows from source		1	3	5	67 Jointworm, wheat (Harmolita tritici) [flight]	Yd from wheat stubble	58	174	290	450
	Diseased plants, no.		26	22	13		Adults caught, no.	18	9	4	0
10 Potato late blight (Phytophthora infestans) [air currents]	Ft from spore source	100	200	400	500	68 Leafhopper, beet (Circulifer tenellus) [flight]	Mi. from breeding area	15	35	105	215
	Lesions/100 plants, no.	295	90	12	2		Leafhoppers caught, no.	500	150	15	4
11 Potato leaf roll [aphids]	Rows from infected plants	1	2	4	6	69 Leafhopper, potato (Empoasca fabae) [flight]	Mi. from nearest land	3	6	9	10
	Diseased plants, %	21	12	5	1		Leafhoppers caught, no.	38	27	21	20
12 Potato mosaic [insects]	Rows from diseased plants		1	3	6	70 Leafhopper, six-spotted (Macrosteles divinus) [flight, crawling]	Ft from release point	50	100	200	
	Diseased plants, %		36	18	6		Leafhoppers caught, no.	9	3	1	
13 Potato yellow dwarf (Macrosteles divinus) [insects]	Ft from old meadow	1	30	90	135	71 Leafhopper, six-spotted (M. divinus) [flight, crawling]	Ft. from release point	30	225	450	
	Diseased plants, %	80	23	9	4		Days to first recovery	4	13	16	
14 Rust, cedar, apple (Gymnosporangium sp) [air currents]	Yd from infected trees	0	55	220	440	72 Leafhopper, six-spotted (M. divinus) [flight]	Mi. from nearest land	3	6	9	10
	Leaf infections, no.	64	40	26	19		Leafhoppers caught, no.	515	145	37	18
15 Rust, wheat stem (Puccinia graminis) [air currents]	Mi. from known source		200	740	940	73 Locust, migratory (Dissosteira longipennis and Melanoplus mexicanus) [flight]	Mi. from release point	25	125	225	
	Spores collected, no.		13,000	8,000	7,000		Locusts recovered, no.	8	6	5	
16 Rust, white pine blister (Cronartium ribicola) [air currents]	Ft from gooseberry bush	50	250	450	650	74 Mosquito (Anopheles gambiae) [flight]	Mi. from release point	0.75	1.25	1.75	2.25
	Diseased trees, %	75	46	36	29		Mosquitoes caught, no.	3.0	2.2	1.6	1.2
17 Severe streak, raspberries [insects]	Rows from wild brambles	3	8	18	23	75 Mosquito (A. funestus) [flight]	Yd from river bank	100	600	1200	2400
	Diseased plants, no.	165	85	21	1		Mosquitoes caught, no.	180	14	5	4
18 Smut, loose, wheat (Ustilago tritici) [air currents]	Mi. from spore source	2	4	24	80	76 Mosquito (A. quadrimaculatus) [flight]	Mi. from breeding area	0.1	0.5	2.0	2.5
	Smutted heads, no.	240	235	115	0		Mosquitoes caught, no.	5000	1850	33	0
Bacteria and Fungi (Miscellaneous)						77 Mosquito (Anopheles spp), incidence of malarial infections	Ft from mosquito source	500	1500	3500	6000
19 Bacterial colonies on sea water medium [air currents]	Mi. from land, over water		5	80	275		Infections, %	36	22	11	4
	Bacterial colonies, no.		41	58	65	78 Mosquito, pest (Aedes and Culex spp) [flight]	Mi. from release point	1	4	8	12
20 Bacterial colonies on sea water medium [air currents]	Mi. from sea, over land		0	0.25	1		Mosquitoes caught, no.	97	37	17	6.3
	Bacterial colonies, no.		550	215	140	79 Mosquito, rice field (Psorophora confinnis) [flight]	Mi. from release point	0.5	2.5	4.5	8.5
21 Spores (Bovista plumbea) [air currents]	Mi. from release point	5	10	15	20		Mosquitoes caught, no.	3.7	1.8	1.1	0.4
	Spores caught, no.	910	325	165	100	80 Mosquito, southern house (Culex quinquefasciatus) [flight]	Mi. from release point	0.8	1.4	2.0	2.6
22 Spores (Tilletia tritici) [air currents]	Mi. from release point	5	10	15	20		Mosquitoes caught, no.	2.8	2.0	1.4	1.0
	Spores caught, no.	800	170	50	30	81 Mosquito, yellow fever (Aedes and other spp) [flight], incidence of yellow fever	Mi. from original case	17.5	32.5	47.5	92.5
Plants (Seeds and Pollen)							Yellow fever cases, no.	14.6	4.6	1.7	0.6
23 Bean, common (Phaseolus vulgaris) [air currents; insects(?)]	Yd from lima bean	1	2	3	5	82 Moth (Catocala spp) [flight]	Ft from release point	13	88	240	365
	Cross pollination, %	9	7	6	4		Moths recovered, no.	8.1	3.7	1.5	0.6
24 Bean, lima (P. lunatus) [air currents; insects(?)]	Yd from common bean	1	2	3	5	83 Moth, codling (Carpocapsa pomonella) [flight]	Ft from release point	75	190	265	330
	Cross pollination, %	5	4	3	2		Moths recovered, %	57	25	13	5
25 Cedar, western red (Juniperus scopularum) [air currents]	Yd from seed source	22	44	66	88	84 Moth, gypsy, males (Porthetria dispar) [flight]	Ft from moth source	330	660	1300	2600
	Seedlings per acre	615	175	55	9		Moths recovered, no.	67	22	5	4
26 Clover, alsike (Trifolium hybridum) [honey bees]	Yd from bee colonies		5.5	440	880	85 Moth, gypsy, larva (P. dispar) [carried by wind]	Ft from source	50	150	250	350
	Seeds per head, no.		38	33	32		Larvae, no.	16	4.4	1.7	1.3
27 Corn (Zea mays) [air currents]	Ft from contaminant		5.5	55.5	90	86 Moth, oriental fruit (Grapholita molesta) [flight]	Ft from orchard		100	1300	2600
	Cross pollination, %		25	11	8		Moths recovered, no.		194	14	8
28 Fir, Douglas (Pseudotsuga taxifolia) [air currents]	Ft from seed trees	2	4	6	8						
	Seedlings per acre	300	170	90	35						

444. SEA WATER: CHARACTERISTICS

Part I: PHYSICAL PROPERTIES AND CHEMICAL CONSTITUENTS

Values are per kg of water, unless otherwise indicated; values in parentheses are ranges.

General Characteristics					Value		Average Surface Temperature, °C				Major Constituents (concluded)			
							Latitude	Atlantic Ocean	Indian Ocean	Pacific Ocean	Substance	Value		
1	Density				1.02-1.03									
2	Temperature				-1.5 to 30°C									
3	pH, surface water				8.1-8.3	46	70-60 N	5.60			89	Sodium	10.56 g	
4	pH, at depth				7.5-8.1	47	60-50 N	8.66		5.74	90	Magnesium	1.27 g	
5	Freezing point				-2°C ¹	48	50-40 N	13.16		9.99	91	Calcium	0.40 g	
6	Specific heat				0.93 Cal/g ²	49	40-30 N	20.40		18.62	92	Potassium	0.38 g	
7	Velocity of sound				1450-1550 m/sec	50	30-20 N	24.16	26.14	23.38	93	Strontium	13 mg	
8	Transparency, maximum ³				66 m	51	20-10 N	25.81	27.23	26.42	Element ^{8,9}			
9	Hydrostatic pressure ⁴				1 atm/10 m	52	10-0 N	26.66	27.88	27.20	94	Chlorine	18.98 g	
	Salinity ⁵				g/kg	53	70-60 S	-1.30	-1.50	-1.30	95	Sodium	10.56 g	
10	All oceans, average				35(33-37)	54	60-50 S	1.76	1.63	5.00	96	Magnesium	1.27 g	
11	All oceans, below 1000 m (at -0.5 to 5°C)				34.6-35	55	50-40 S	8.68	8.67	11.16	97	Sulfur	0.88 g	
12	Great depths (1-4°C)				34-35.2	56	40-30 S	16.90	17.00	16.98	98	Calcium	0.40 g	
13	At equator (average all oceans)				35	57	30-20 S	21.20	22.53	21.53	99	Potassium	0.38 g	
14	20th-40th parallel, N. Latitude				35.5	58	20-10 S	23.16	25.85	25.11	100	Bromine	65 mg	
15	10th-30th parallel, S. Latitude				35.5	59	10-0 S	25.18	27.41	26.01	101	Carbon	28 mg	
16	Average, 60°N. and S. Latitudes to the poles				35	Relation of Chlorinity and Salinity to Specific Gravity				102	Strontium	13 mg		
17	North Pacific				34.5	Chlorinity ⁷ Salinity ⁵ Specific Gravity				103	Boron	4.6 mg		
18	North Sea, off Denmark				34		g/kg	g/kg		at 17.5°C	104	Silicon	0.02-4.0 mg	
19	Indian Ocean, near Australia				35.5	60	0	0.00		1.00000	105	Fluorine	1.4 mg	
20	South Pacific, off Peru				35.5	61	1	1.84		1.00144	106	Nitrogen (comp.)	0.006-0.7 mg	
21	Arabian Sea				36-37	62	2	3.64		1.00283	107	Aluminum	70 µg	
22	Sargasso Sea, N. Atlantic				36.5-37	63	3	5.45		1.00421	108	Rubidium	0.2 mg	
23	South Atlantic, off Brazil				36-37	64	4	7.25		1.00558	109	Lithium	0.1 mg	
24	Red Sea (surface)				38-41	65	5	9.06		1.00696	110	Phosphorus	1-100 µg	
25	Mediterranean Sea (surface)				37-39	66	6	10.86		1.00834	111	Barium	54 µg	
26	Gulf of Mexico (surface)				36-37	67	7	12.67		1.00971	112	Iodine	50 µg	
27	Antarctic Ocean (surface)				34-34.6	68	8	14.47		1.01109	113	Arsenic	10-20 µg	
28	Arctic Ocean (surface)				32-33	69	9	16.28		1.01246	114	Iron	2-50 µg	
Pressure-Depth Gradient ⁴						70	10	18.08		1.01383	115	Manganese	1-10 µg	
	Depth	Salinity	Temp	Latitude	Latitude	71	11	19.89		1.01521	116	Copper	1-10 µg	
	m	g/kg	°C	30°	60°	72	12	21.69		1.01658	117	Zinc	5 µg	
				atm/m	atm/m	73	13	23.50		1.01795	118	Lead	5 µg	
29	0	32	0	0.099141	0.099403	74	14	25.30		1.01933	119	Selenium	4 µg	
30	0	32	20	0.098831	0.099092	75	15	27.11		1.02070	120	Cesium	2 µg	
31	0	35	0	0.099375	0.099638	76	16	28.91		1.02208	121	Uranium	2 µg	
32	0	35	20	0.099052	0.099314	77	17	30.72		1.02346	122	Molybdenum	0.7 µg	
33	5000	35	0	0.101757	0.102026	78	18	32.52		1.02484	123	Gallium	0.5 µg	
34	5000	35	5	0.101660	0.101929	79	19	34.33		1.02622	124	Thorium	0.4 µg	
35	10,000	35	0	0.103952	0.104225	80	20	36.13		1.02760	125	Cerium	0.4 µg	
Oxygen Saturation Values from Normal Dry Atmosphere						81	21	37.94		1.02899	126	Silver	0.3 µg	
36	Chlorinity	15	16	17	18	19	20				127	Vanadium	0.3 µg	
37	Salinity	27.11	28.91	30.72	32.52	34.33	36.11				128	Lanthanum	0.3 µg	
	Temp	Oxygen ml/L ⁶						Major Constituents ⁸				129	Yttrium	0.3 µg
	°C											130	Bismuth	0.2 µg
38	-2	9.01	8.89	8.76	8.64	8.52	8.39					131	Nickel	0.1 µg
39	0	8.55	8.43	8.32	8.20	8.08	7.97					132	Scandium	0.04 µg
40	5	7.56	7.46	7.36	7.26	7.16	7.07					133	Mercury	0.03 µg
41	10	6.77	6.69	6.60	6.52	6.44	6.35					134	Gold	0.004 µg
42	15	6.14	6.07	6.00	5.93	5.86	5.79					135	Radium	0.2-0.3 x 10 ⁻¹⁰ µg
43	20	5.63	5.56	5.50	5.44	5.38	5.31					136	Cadmium	Present
44	25	5.17	5.12	5.06	5.00	4.95	4.86					137	Chromium	Present
45	30	4.74	4.68	4.63	4.58	4.52	4.46					138	Cobalt	0.1 µg
												139	Tin	3 µg
												</		

/1/ Value for water with salinity of slightly more 35 g/kg. /2/ Specific heat is a function of temperature, pressure and humidity; 0.93 approximates the value for sea water with a salinity of 34.85 g/kg at 20°C and atmospheric pressure (760 mm Hg). /3/ In Sargasso Sea, where a 30 cm Secchi disk disappears from sight at this depth. /4/ Hydrostatic pressure increases approximately 1 atmosphere (760 mm Hg) for each 10 m of depth, the exact value being affected by salinity, temperature and latitude. /5/ Total amount of solid material in g/kg of sea water when all carbonate has been converted to oxide, Br and I replaced by Cl, and all organic matter completely oxidized. /6/ mg-atoms of oxygen per liter = 0.08931 x ml/L (these values may be 3% too high). /7/ Chlorinity refers to total amount of Cl, Br and I in g/kg of sea water, and is equal to the mass, in grams, of "atomic weight silver" just necessary to precipitate the halogens in 0.3285233 kg. The standard chlorinity of sea water is 19, and equals salinity 34.325. /8/ Based on total salinity of 34.325. /9/ Nitrogen, oxygen, neon, helium and argon are also present as dissolved gases.

Part II: MARINE PLANT DISTRIBUTION

Flora	Distribution
1 Seed plants (Spermatophyta)	None in deep oceans beyond continental shelves; 30 genera near coasts in 10-40 ft depths, all in 2 families (Hydrocharitaceae, Potamogetonaceae) as Halophila, Zostera, Thalassia, Phyllospadix.
2 Algae (Thallophyta)	Continental shelves all oceans with average salinity of 35, within 100 m depths; abundant near river mouths.
3 Blue-green (Myxophyceae)	Not abundant; nodularia in Norway fiords, Trichodesmium in Red Sea.
4 Green (Chlorophyceae)	Enteromorpha, Ulva in bays and harbors near surface; Codium, Halimeda (calcareous) ¹ in tropics.
5 Brown (Phaeophyceae)	Ascophyllum, Fucus (smaller rock weeds); Laminaria, Nereocystis, Postelsia (large kelps), attached to rocks in deeper water; Sargassum floating in Central Atlantic.
6 Red (Rhodophyceae)	Small forms can live beyond continental shelves in depths of 30 m or more; Corallina of tropics is calcareous. ¹
7 Fungi and bacteria	In mud and ooze of ocean floors - no other plant life.
8 Plankton	On surface all oceans; diatoms, dinoflagellates, coccolithophores; microscopic, important food for sea animals.

/1/ Contributing to sand (lime) deposits.

445. GEOLOGIC DISTRIBUTION: PLANTS, ANIMALS

M = million; B = billion.

Era (Duration, yr)	Major Division	Period (Years Ago)	Epoch	Duration yr	Advances in Life	Dominant Life
1 Cenozoic (60 M)	Quaternary	(2 M)	Recent	2 M	Rise of civilization.	Age of man and herbaceous plants.
			Pleistocene		Periodic glaciation; extinction of great mam- mals and many trees; rise of modern herbs; elevation of continents.	
	Tertiary	Late Tertiary	Pliocene	58 M	Continued cooling of climate; elevation of Andes; increasing restriction of plant distri- bution and forests; appearance of man.	Age of modern life: mammals, birds, flowering plants.
			Miocene		Climate changing greatly, becoming cool and semi-arid; elevation of Alps; restriction of distribution of plants; beginning of forest reduction; culmination of many mammals.	
		Early Tertiary	Oligocene		Climate warm, humid; elevation of Pyrenees; culmination of Eocene floras; world-wide distribution of tropical forests; primitive mammals disappear; rise of higher mam- mals and birds.	
			Eocene		Climate cool, semi-arid, then warm, humid; modernization of flowering plants; develop- ment of extensive forests, widespread in polar regions; modern birds and marine mammals appear.	
	2 Mesozoic (125 M)	Cretaceous	(125 M)	Upper Cretaceous	65 M	Climate fluctuating; angiosperms dominant in floras, dicotyledons and monocotyledons of numerous existing genera well developed; disappearance of Bennettitales; rise of primitive mammals.	Age of reptiles and higher gymnosperms.
Middle Cretaceous				Climate fluctuating; rapid development of angiosperms, appearance of many existing genera; specialization and extinction of great reptiles.		
Lower Cretaceous				Climate very warm; rise of angiosperms(?); conifers and cycads still dominant; earliest known pines (Pinaceae).		
Jurassic		Jurassic	32 M	Climate warm; beginning of Sierra Nevada Mountains; first certainly known angio- sperms; conifers and cycads dominant; Ginkgoales and conifers world-wide; cordaites disappear; primitive birds and flying reptiles; rise of higher insects.		
Triassic		Triassic	28 M	Climate warm, semi-arid; floras not luxuriant; gymnosperms increase, spread of conifers, rise of cycads and Bennettitales; seed ferns disappear; diversification of modern fern families well started; first mammals; rise of giant reptiles (dinosaurs).		
3 Paleozoic (368 M)	Late Paleozoic	Carboniferous	Permian (223 M)	38 M	Climate dry; periodic glaciation, severe in southern hemisphere, elevation of Appa- lachians; dwindling of ancient groups, ex- tinction of many; rise of ferns and conifers and land vertebrates; expansion of reptiles. Gondwana flora of southern hemisphere distinct from northern.	Age of amphibians, lycopods, and seed ferns.
			Pennsylvanian (271 M)		Dominant lycopods, seed ferns, horsetails; sphenophylls, Coniferales and calamites present; extensive coal formation.	
			Mississippian (309 M)		Dominant lycopods, horsetails, seed ferns; cordaites, sphenophylls, calamites present; rise of primitive reptiles and insects.	
	Middle Paleozoic	Devonian	Devonian	45 M	Early land floras: Psilophytales (Rhynia, Horneophyton); lycopods; primitive horse- tails, including sphenophylls; primitive gymnosperms (earliest Cordaites and seed ferns, their seeds not yet known); first forests; rise of amphibians and fishes.	Age of fishes and early land plants.
			Silurian (381 M)	Algae dominant (e.g., Nematophyton hecksii); first known land plants: Psilophytales and Lycopodiales, e.g., Baragwanathia; rise of lungfishes and scorpions (first air-breath- ing animals).		
	Early Paleozoic	Cambrian	Ordovician (448 M)	67 M	Rise of corals, armored fishes (and land plants ?); marine algae dominant; first known fresh-water fishes.	Age of higher invertebrates and algae.
			Cambrian (553 M)	105 M	Climate warm, uniform over earth; first abun- dant fossils; many groups of marine inverte- brates; dominant trilobites; marine plants, few algae determinable; Cambrian spores, pollen, tracheids in India, north-central Europe and Scandinavia.	
	4 Proterozoic (900 M)		Precambrian (1.5 B)	Precambrian		Rocks chiefly sedimentary, of enormous thick- ness; glaciation; first fossils: worms, crus- taceans, brachiopods; evidence of algal and bacterial life described.	Age of primitive marine invertebrates; fossils rare.
5 Archeozoic (550 M+)		(3.5-5 B)			Igneous rocks: lavas, metamorphosed rocks; few sedimentary; no direct evidence of life; graphites of possible organic origin in sedi- mentary rocks of Grenville age.	Age of unicellular life (?); fossils unknown.

Appendix

APPENDIX I: TAXONOMIC CLASSIFICATION: ANIMALS

Classification adapted from A. S. Pearse's "Zoological Names," Section F, American Association for the Advancement of Science, Durham, North Carolina, 1948. Extinct groups are indicated by an asterisk (*).

KINGDOM: ANIMALIA	Order: Asconosa	Order: Pseudophyllidea
Subkingdom: Protozoa	Order: Syconosa	Order: Cyclophyllidea
I. PHYLUM: PROTOZOA	Class: Hyalospongiae	Order: Tetraphyllidea
Subphylum: Plasmodroma	Order: Hexasterophora	Order: Trypanorhyncha
Class: Mastigophora	Order: Amphidiscophora	Order: Heterophyllidea
Subclass: Phytomastigina	Class: Desmospongiae	VII. PHYLUM: NEMERTEA
Order: Chrysomonadina	Order: Carnosa	Class: Anopla
Suborder: Euchrysomonadina	Order: Choristida	Order: Paleonemertea
Suborder: Rhizochrysidina	Order: Epipolasida	Order: Heteronemertea
Suborder: Chrysocapsina	Order: Hadromerina	Class: Enopla
Order: Cryptomonadina	Order: Poecilosclerina	Order: Hoplonemertea
Suborder: Eucryptomonadina	Order: Haplosclerina	Suborder: Monostilifera
Suborder: Phoeocapsina	Order: Keratosa	Suborder: Polystilifera
Order: Phytomonadina	III. PHYLUM: *ARCHAEOCYATHA	Order: Bellonemertea
Order: Euglenoidina	Subkingdom: Metazoa	VIII. PHYLUM: ACANTHOCEPHALA
Order: Chloromonadina	Subkingdom: Enterozoa	Class: Eoacanthocephala
Order: Dinoflagellata	IV. PHYLUM: COELENTERATA	Order: Gyraacanthocephala
Suborder: Porocentrinea	Class: Hydrozoa	Order: Neocanthocephala
Suborder: Peridininea	Order: Hydroida	Class: Metacanthocephala
Suborder: Cystoflagellata	Order: Trachylina	Order: Palaeacanthocephala
Subclass: Zoomastigina	Order: Milleporina	Order: Archiacanthocephala
Order: Rhizomastigina	Order: Stylasterina	IX. PHYLUM: PROSOPIGIA
Order: Protomonadina	Order: Siphonophora	X. PHYLUM: ROTATORIA
Order: Polymastigina	Class: Scyphozoa	Class: Seisonidea
Suborder: Monomonadina	Order: Lucernariidea	Class: Bdelloidea
Suborder: Diplomonadina	Order: Charybdeidea	Class: Monogononta
Suborder: Polyomonadina	Order: Corona	Order: Ploima
Order: Hypermastigina	Order: Semaestomatae	Order: Flosculariacea
Class: Sarcodina	Order: Rhizostomatae	Order: Collothecacea
Subclass: Rhizopoda	Class: Anthozoa	XI. PHYLUM: GASTROTRICHA
Order: Proteomyxa	Subclass: Octocorallia	Order: Macrodasyoidea
Order: Mycetozoa	Order: Stolonifera	Order: Chaetonotoidea
Suborder: Eumycetozoa	Order: Telestacea	XII. PHYLUM: ECHINODERA
Suborder: Sorophora	Order: Alcyonacea	XIII. PHYLUM: NEMATOMORPHA
Order: Amoebina	Order: *Trachysammiacea	Class: Gordiidea
Order: Testacea	Order: Coenothecalia	Class: Nectonematoidea
Order: Foraminifera	Order: Gorgonacea	XIV. PHYLUM: NEMATOIDEA
Subclass: Actinopoda	Suborder: Scleraxonia	Class: Phasmodia
Order: Heliozoa	Suborder: Holaxonia	Order: Rhabditida
Order: Radiolaria	Order: Pennatulacea	Suborder: Rhabditata
Class: Sporozoa	Suborder: Sessiliflorae	Suborder: Ascaridata
Subclass: Telosporidia	Suborder: Subselliiflorae	Suborder: Strongylata
Order: Gregarinida	Subclass: Zoantharia	Order: Spirurida
Suborder: Eugregarinaria	Order: Cerinthisidea	Suborder: Spirurata
Suborder: Schizogregarinaria	Order: Antipatharia	Suborder: Camallanata
Order: Coccidia	Order: Zoanthidea	Class: Aphasmodia
Suborder: Eimeridea	Order: Actinaria	Order: Enoplata
Suborder: Adeleidea	Suborder: Ptychodactylaria	Suborder: Enoplata
Order: Haemosporidia	Suborder: Corallimorpharia	Suborder: Dorylaimata
Subclass: Acnidosporidia	Suborder: Actiniaria	Suborder: Diotrophymata
Order: Sarcosporidia	Order: Scleractinia	Order: Chromadorida
Order: Haplosporidia	Suborder: Astrocoeniida	Suborder: Monohysterata
Subclass: Cnidosporidia	Suborder: Fungiida	Suborder: Desmoscolecata
Order: Myxosporidia	Suborder: Faviida	Suborder: Chromadorata
Suborder: Eurysporea	Suborder: Caryophylliida	XV. PHYLUM: TARDIGRADA
Suborder: Sphaerosporea	Suborder: Dendrophylloida	Class: Heterotardigrada
Suborder: Platysporea	Order: Rugosa	Order: Arthrotardigrada
Order: Actinomyxidina	Order: Tabulata	Order: Echiniscoidea
Order: Microsporidia	V. PHYLUM: CTENOPHORA	Class: Eutardigrada
Suborder: Monocnidea	Class: Tentaculata	XVI. PHYLUM: CHAETOGNATHA
Suborder: Dicinidea	Order: Cydippidea	XVII. PHYLUM: BRYOZOA
Order: Helicosporidia	Order: Lobata	Class: Entoprocta
Subphylum: Ciliophora	Order: Cestoidea	Class: Ectoprocta
Class: Ciliata	Order: Platyctenea	Subclass: Gymnolaemata
Subclass: Protociliata	Class: Nuda	Order: Cyclostomata
Subclass: Euciliata	Order: Beroidea	Suborder: Tubipora
Order: Holotricha	VI. PHYLUM: PLATYHELMINTHES	Suborder: Ceriopora
Suborder: Astomata	Class: Turbellaria	Suborder: Ceramoporoida
Suborder: Gymnostomata	Order: Acoela	Suborder: Hederelloidea
Suborder: Trichostomata	Order: Rhabdocoela	Order: Trepostomata
Suborder: Hymenostomata	Suborder: Temnocephalida	Order: Cryptostomata
Suborder: Thigmotricha	Order: Alloicoela	Order: Ctenostoma
Suborder: Apostomea	Order: Tricladida	Order: Cheilostomata
Order: Spirotricha	Order: Polycladida	Suborder: Anasca
Suborder: Heterotricha	Class: Trematoda	Suborder: Ascophora
Suborder: Oligotricha	Subclass: Monogenea	Subclass: Phylactolaemata
Suborder: Ctenostomata	Order: Monopisthocotylea	XVIII. PHYLUM: BRACHIOPODA
Suborder: Hypotricha	Order: Polyopisthocotylea	Class: Inarticulata
Order: Chyotricha	Subclass: Aspidogastrea	Order: Atremata
Order: Peritricha	Subclass: Digenea	Order: Neotremata
Suborder: Sessilia	Order: Gasterostoma	Class: Articulata
Suborder: Mobilia	Order: Prosostomata	Order: *Paleotremata
Class: Suctorina	Class: Cestoidea	Order: Protremata
Subkingdom: Mesozoa	Subclass: Cestoidaria	Order: Telotremata
Subkingdom: Parazoa	Order: Amphiliinea	XIX. PHYLUM: PHORONIDEA
II. PHYLUM: PORIFERA	Order: Gyrocotylidea	XX. PHYLUM: POEBIOIDEA
Class: Calcispongiae	Subclass: Cestoda	XXI. PHYLUM: POGONOPHORA

APPENDIX I. TAXONOMIC CLASSIFICATION: ANIMALS (Continued)

XXII. PHYLUM: PTEROBRANCHIA	Order: Echiuroinea	Infraclass: Leptostraca
XXIII. PHYLUM: ENTEROPNEUSTA	Order: Xenopneusta	Superorder: Phyllocarida
Class: Balanoglossida	Order: Heteromyota	Order: Nebaliacea
XXIV. PHYLUM: LINGUATULA	Class: Saccosomatida	Order: *Rhinoecarina
XXV. PHYLUM: ECHINODERMATA	XXIX. PHYLUM: SIPUNCULOIDEA	Order: *Ceraticarina
Subphylum: Peletozoa	XXX. PHYLUM: ONYCHOPHORA	Order: *Hymenocarina
Class: *Cystoidea	XXXI. PHYLUM: ARTHROPODA	Superorder: *Nahecarida
Order: *Amphoridea	Subphylum: *Trilobita	Infraclass: Eumalacostraca
Order: *Rhombifera	Class: *Hypoparia	Superorder: Syncarida
Order: *Diploporita	Class: *Opisthoparia	Order: Anaspidacea
Order: *Aporita	Class: *Proparia	Superorder: Peracarida
Order: *Edrioasteroidea	Subphylum: Chelicerata	Order: Mysidacea
Class: *Blastoidea	Class: Merostomata	Order: Thermosbaenacea
Order: *Protoblastoidea	Order: *Eurypterida	Order: Cumania
Order: *Eublastoidea	Order: *Synxiphosura	Order: Tanaidacea
Class: Crinoidea	Order: Xiphosura	Order: Isopoda
Order: *Camerata	Class: Pycnogonida	Suborder: Flabellifera
Order: *Adunata	Order: Colossendeomorpha	Suborder: Valvifera
Order: Flexibilia	Order: Nymphonomorpha	Suborder: Asellota
Suborder: *Sagenocrinida	Order: Ascorhynchomorpha	Suborder: Phreatoicoidea
Suborder: *Taxocrinida	Order: Pycnogonomorpha	Suborder: Epicaridea
Order: *Inadunata	Class: Arachnida	Suborder: Oniscoidea
Suborder: *Larviformia	Subclass: Latigastrea	Order: Amphipoda
Suborder: *Fistulata	Order: Scorpiones	Suborder: Gammaridea
Order: Articulata	Order: Pseudoscorpiones	Suborder: Hyperidea
Suborder: Bourgueticrinida	Order: Opiliones	Suborder: Caprellidea
Suborder: Pentacrinida	Order: *Architarbi	Suborder: Ingolfiellidea
Suborder: Holopoda	Order: Acari	Superorder: Eucarida
Order: Comatulida	Suborder: Notostigmata	Order: Euphausiacea
Suborder: Oligophreata	Suborder: Holothyroidea	Order: Decapoda
Suborder: Macrophreata	Suborder: Parasitiformes	Suborder: Natantia
Subphylum: Asterozoa	Suborder: Trombidiformes	Suborder: Reptantia
Class: Asteroidea	Suborder: Sarcotiformes	Superorder: Hoplocarida
Order: Phanerozoonea	Suborder: Tetraptidii	Order: Stomatopoda
Order: Spinulosa	Subclass: Stethostomata	Superclass: Progonata
Order: Forcipulata	Order: *Haptopoda	Class: Pauropoda
Class: Ophiuroidea	Order: *Anthracomarti	Order: Pauropoda
Subclass: *Aegophiurida	Subclass: Soluta	Suborder: Ectomorpha
Order: *Lysophiurida	Order: Trigonotarbi	Suborder: Endomorpha
Subclass: Myophiurida	Subclass: Caulogastrea	Class: Symphyla
Order: *Ophiocystiida	Superorder: Latisterna	Order: Symphyla
Order: *Aganasterida	Order: Palpigradi	Class: Diplopoda
Order: Phrynophiurida	Superorder: Camarostomata	Subclass: Pselaphognatha
Order: Laemophiurida	Order: Schizomida	Order: Ancyrotricha
Order: Gnathophiurida	Order: Telyphonida	Order: *Lophotricha
Order: Chilophiurida	Order: Kustarachnae	Subclass: Chilognatha
Subphylum: Echinozoa	Superorder: Labellata	Superorder: Opisthondria
Class: Echinoidea	Order: Phrynichida	Order: Limacomorpha
Order: *Bothriocidaroida	Order: Araneae	Order: Oniscoomorpha
Order: Cidaroida	Superorder: Cucullifera	Suborder: Sphaerotheria
Order: Centrechinoidea	Order: Ricinulei	Suborder: Glomeridia
Suborder: Aulodonta	Superorder: Rostrata	Superorder: Proterandria
Suborder: Stirodonta	Order: Solifugae	Order: Colobognatha
Suborder: Camerodonta	Subphylum: Mandibulata	Order: Nematophora
Order: Exocycloidea	Superclass: Crustacea	Suborder: Chordeumoidea
Suborder: Holoctypina	Class: Eucrustacea	Suborder: Stemmuloidea
Suborder: Echinoneina	Subclass: Branchiopoda	Suborder: Striaroidea
Suborder: Clypeastrina	Order: Anostraca	Suborder: Lysioptaloidea
Suborder: Nucleolitina	Order: Notostraca	Order: Proterospermophora
Suborder: Cassidulina	Order: Conchostraca	Suborder: Polydesmoidea
Suborder: Urechinina	Order: Cladocera	Suborder: Strongylosomoidea
Suborder: Spatangina	Suborder: Calyptomera	Order: Opisthospermophora
Order: Perischoechinoida	Suborder: Gymnomera	Suborder: Julioidea
Order: Echinocystoida	Subclass: Ostracoda	Suborder: Spiroboloidea
Order: Perichoechinoida	Order: Myodocopa	Suborder: Spirostreptoidea
Class: Holothurioida	Order: Cladocopa	Suborder: Cambaloidea
Order: Dendrochirota	Order: Podocopa	Superclass: Opisthogoneata
Order: Elaspoda	Order: Platyocopa	Class: Chilopoda
Order: Aspidochirota	Subclass: Copepoda	Subclass: Pleurostigmomorphora
Order: Molpadonia	Order: Eucopopoda	Superorder: Epimorpha
Order: Apoda	Suborder: Calanoida	Order: Geophilomorpha
XXVI. PHYLUM: PRIAPULOIDEA	Suborder: Harpacticoida	Order: Scolopendromorpha
XXVII. PHYLUM: ANNELIDA	Suborder: Cyclopoida	Superorder: Anamorpha
Class: Archannelida	Suborder: Notodelphyoida	Order: Lithobiomorpha
Class: Polychaeta	Suborder: Monstrilloidea	Order: Craterostigmomorphora
Order: Errantia	Suborder: Caligoida	Subclass: Notostigmomorphora
Order: Sedentaria	Suborder: Lernaepodoida	Order: Scutigeromorpha
Class: Myzostoma	Order: Branchiura	Class: Insecta
Class: Oligochaeta	Suborder: Arguloida	Subclass: Synaptera
Order: Plesioptera plesiotheca	Subclass: Cirripedia	Order: Collembola
Order: Plesioptera prosiotheca	Order: Thoracica	Order: Protura
Order: Prosopora	Suborder: Turrilepadomorpha	Order: Entotrophia
Order: Opisthopora	Suborder: Lepadomorpha	Order: Thysanura
Class: Hirudinea	Suborder: Verrucomorpha	Subclass: Pterygota
Order: Rhynchobdellida	Suborder: Balanomorphia	Order: Odonata
Order: Gnathobdellida	Order: Ascothoracica	Order: Ephemeroptera
Order: Pharyngobdellida	Order: Apoda	Order: Orthoptera
XXVIII. PHYLUM: ECHIUROIDEA	Order: Rhizocephala	Order: Isoptera
Class: Echiurida	Subclass: Malacostraca	Order: Dermaptera

APPENDIX I. TAXONOMIC CLASSIFICATION: ANIMALS (Continued)

Order: Plecoptera	Suborder: Gymnosomata	Order: Galeida
Order: Embioptera	Order: Sacoglossa	Suborder: Galeina
Order: Psocoptera	Order: Acoela	Order: Squalida
Order: Zoraptera	Suborder: Notaspidea	Suborder: Squalina
Order: Mallophaga	Suborder: Nudibranchia	Order: Squatinida
Order: Anoplura	Subclass: Pulmonata	Suborder: Squatinina
Order: Hemiptera	Order: Basommatophora	Order: Pristiophorida
Suborder: Heteroptera	Order: Stylommatophora	Superorder: Rajica
Suborder: Homoptera	Class: Scaphopoda	Order: Rajida
Order: Thysanoptera	Class: Pelecypoda	Suborder: Prostiina
Order: Neuroptera	Subclass: Prionodesmacea	Suborder: Rhinobatina
Suborder: Megaloptera	Order: Palaeoconcha	Suborder: Totpedinina
Suborder: Raphidioidea	Order: Taxodonta	Suborder: Rajina
Suborder: Planipennia	Order: Schizodonta	Suborder: Dasyatina
Order: Mecoptera	Order: Dysodonta	Subclass: Holocephali
Order: Diptera	Subclass: Anomalodesmacea	Order: *Bradyodontida
Suborder: Nematocera	Order: Anomalobanchia	Order: Chimaerida
Suborder: Brachycera	Order: Septibranchia	Class: Osteichthyes
Order: Siphonaptera	Subclass: Teleodesmacea	Subclass: Choanichthyes
Order: Trichoptera	Order: *Pantodonta	Order: Neoceratodontida
Order: Lepidoptera	Order: Diogenodonta	Order: Crossopterygida
Suborder: Jugatae	Order: Cyclodonta	Suborder: *Rhipidistiina
Suborder: Frenatae	Order: Teleodonta	Suborder: Coelacanthina
Suborder: Rhopalocera	Order: Asthenodonta	Subclass: Actinopterygii
Order: Coleoptera	Class: Cephalopoda	Superorder: Chondrosteica
Suborder: Adephaga	Order: Tetrabranchia	Order: *Palaeoniscida
Suborder: Polyphaga	Suborder: Nautiloidea	Order: Polypterida
Order: Hymenoptera	Suborder: *Ammonitoidea	Order: Acipenserida
Suborder: Chalcidogastra	Order: Dibranchia	Order: *Subholosteida
Suborder: Clitogastra	Suborder: Vampyromorpha	Superorder: Holosteica
Order: *Palaeodictyoptera	Suborder: Decapoda	Order: Lepisosteida
Order: *Megasecoptera	Suborder: Octopoda	Order: *Pycnodontida
Order: *Protephemerida	XXXIII. PHYLUM: CHORDATA	Order: *Aspidorhynchida
Order: *Protodonata	Subphylum: Tunicata	Order: Amiida
Order: *Protopterygia	Class: Ascidiacea	Order: *Pholidophorida
Order: *Protelytroptera	Order: Stolidobranchiata	Superorder: Teleosteica
Order: *Caloneuroidea	Order: Aspiraculata	Order: Isospondyliida
Order: *Glosselytroidea	Order: Phlebobranchiata	Suborder: Clupeina
Order: *Protorthoptera	Order: Aplousobranchiata	Suborder: Salmonina
Order: *Protohemiptera	Class: Larvacea	Suborder: Opisthoproctina
The following orders of insects are listed but have dubious recognition.	Class: Thaliacea	Suborder: Osteoglossina
Order: *Protoblattoidea	Subclass: Myosomata	Suborder: Stomatina
Order: *Hadenomitoidea	Order: Salpida	Suborder: Gymnophotodermina
Order: *Sypharopteroidea	Order: Doliolida	Suborder: *Enchodontina
Order: *Mixotermioidea	Subclass: Pyrosomata	Suborder: Iniomina
Order: *Reculoidea	Order: Pyrosomatida	Suborder: Berycomorphina
Order: *Haplopteroidea	Subphylum: Acrania	Suborder: Escocina
Order: *Protomecoptera	Class: Branchiostomi	Order: Bathyclupeida
Order: *Paratrachoptera	Order: Branchiostomida	Order: Mormyrida
Order: *Paramecoptera	Subphylum: Craniata	Order: Ateleopida
Order: *Synarmogioidea	Superclass: Agnatha	Order: Giganturida
Order: *Diaphanopteroidea	Class: *Cephalaspidocephali	Order: Lyomerida
Order: *Aeroplanoptera	Order: *Osteostracida	Order: Ostariophysida
Order: *Protohymenoptera	Order: *Anaspida	Suborder: Characina
Order: *Protocoleoptera	Class: Petromyzontia	Suborder: Gymnotina
Order: *Miomoptera	Order: Myxiniida	Suborder: Cyprinina
Order: *Pruvostitoptera	Order: Petromyzontida	Suborder: Silurina
Order: *Meganisoptera	Class: *Pteraspidocephali	Order: Anguillida
Order: *Permodonata	Order: *Heterostracia	Order: Heteromida
Order: *Archodonata	Order: *Coelolepida	Order: Synbranchida
Order: *Protodiptera	Order: *Euphanerida	Order: Syngnathida
Order: *Hemipsoptera	Superclass: Gnathostomata (Pisces)	Suborder: Scomberesocina
Order: *Cnemidolestoida	Class: *Placodermi	Suborder: Exocoetina
Order: *Paraplecoptera	Order: *Acanthodiida	Order: Cyprinodontida
Order: *Archaeohymenoptera	Order: *Arthrodira	Suborder: Amblyopsina
Order: *Palaeohymenoptera	Suborder: *Euarthrodira	Suborder: Poeciliina
Order: *Protocicadida	Suborder: *Arctolepina	Order: Salmopercida
Order: *Protofulgorida	Suborder: *Brachythrachina	Order: Zeomorphida
Order: *Hemiodonata	Suborder: *Ptyctodontina	Order: Solenichthyida
Order: *Anisaxia	Suborder: *Phyllolepina	Order: Allotriognathida
Order: *Perielytroidea	Order: *Macropetalichthyida	Order: Anacanthida
Order: *Permodictyoptera	Order: *Antiarchida	Order: Gasterosteida
Order: *Aphelophebia	Order: *Stegoselachida	Order: Percomorphida
XXXII. PHYLUM: MOLLUSCA	Suborder: *Stensioellina	Suborder: Sphyraenina
Class: Crepidopoda	Suborder: *Rhenanina	Suborder: Phallostethina
Order: Eoplacophora	Order: *Palaeospondyliida	Suborder: Polynemina
Order: Mesoplacophora	Class: Chondrichthyes	Suborder: Anabantina
Order: Isoplacophora	Subclass: *Xenacanthi	Suborder: Channina
Order: Teleoplacophora	Order: *Xenacanthida	Suborder: Percina
Class: Gastropoda	Subclass: *Cladoselachii	Suborder: Blenniina
Subclass: Prosobranchia	Order: *Cladoselachida	Suborder: Ophidiina
Order: Archaeogastropoda	Subclass: Selachii	Suborder: Ammodytina
Order: Mesogastropoda	Superorder: Selachiia	Suborder: Schindleriina
Order: Neogastropoda	Order: Hexanchida	Suborder: Callionymina
Subclass: Opisthobranchia	Suborder: Hexanchina	Suborder: Trichiurina
Order: Tectibranchia	Suborder: Chlamydoselachina	Suborder: Scombrina
Order: Pteropoda	Order: Heterodontida	Suborder: Luvarina
Suborder: Thecosomata	Suborder: *Hybodontina	Suborder: Tetragnathina
	Suborder: Heterodontina	Suborder: Stromateina

APPENDIX I. TAXONOMIC CLASSIFICATION: ANIMALS (Concluded)

Suborder: Kurtina	Order: *Pterosauri	Suborder: Meropes
Suborder: *Ramphosina	Suborder: *Rhamphorhynchoidea	Suborder: Coracii
Suborder: Gobina	Suborder: *Pterodactyloidea	Suborder: Buceroles
Order: Scorpaenida	Order: *Saurischia	Order: Piciformes
Order: Cephalacanthida	Suborder: *Theropoda	Suborder: Galbulae
Order: Pegasida	Suborder: *Sauropoda	Suborder: Pici
Order: Pleuronectida	Order: *Ornithischia	Order: Passeriformes
Suborder: Psettodina	Suborder: *Ornithopoda	Suborder: Eurylaimi
Suborder: Soleina	Suborder: *Ankylosauria	Suborder: Tyranni
Order: Icosteida	Suborder: *Ceratopsia	Suborder: Menurae
Order: Chaudhurida	Subclass: *Synapsida	Suborder: Passeres
Order: Mastocembelida	Order: *Pelycosauria	Class: Mammalia
Order: Echeneida	Suborder: *Ophiacodontia	Subclass: Prototheria
Order: Tetraodontida	Suborder: *Sphenacodontia	Order: Monotremata
Suborder: Balistina	Suborder: *Edaphosauria	Subclass: *Allotheria
Suborder: Ostraciontina	Order: *Therapsida	Order: *Multituberculata
Suborder: Tetraodontina	Suborder: *Dinocephalia	Order: *Triconodontia
Suborder: Diodontina	Suborder: *Dicynodontia	Subclass: Theria
Suborder: Molina	Suborder: *Theriodontia	Infraclass: *Pantotheria
Order: Gobiesocida	Order: *Ictidosauria	Order: *Pantotheria
Order: Batrachoidida	Class: Aves	Order: *Symmetrodonta
Order: Lophiida	Subclass: *Archaeornithes	Infraclass: Metatheria
Suborder: Lophiina	Order: Archaeopterygiformes	Order: Marsupialia
Suborder: Antennariina	Subclass: Neornithes	Infraclass: Eutheria
Suborder: Ceratiina	Superorder: *Odontognathae	Cohort: Unguiculata
Superclass: Tetrapoda	Order: *Hesperornithiformes	Order: Insectivora
Class: Amphibia	Order: *Ichthyornithiformes	Order: Dermoptera
Superorder: *Labyrinthodontia	Superorder: Palaeognathae	Order: Chiroptera
Order: *Ichthyostegalia	Order: Caenagnathiformes	Suborder: Megachiroptera
Order: *Rhachitomic	Order: Struthioniformes	Suborder: Microchiroptera
Suborder: *Loxommoidea	Order: Rheiformes	Order: Primates
Suborder: *Edopoidea	Order: Casuariiformes	Suborder: Prosimii
Suborder: *Eryopoidea	Order: *Dinornithiformes	Suborder: Anthropoidea
Suborder: *Neorhachitomi	Order: *Aepyornithiformes	Order: *Tillodontia
Order: *Stereospondyli	Order: Tinamiformes	Order: *Taeniodontia
Order: *Embolomeri	Order: Impennes	Order: Edentata
Order: *Seymouriamorpha	Superorder: Neognathae	Suborder: *Palaeonodonta
Order: *Eoanura	Order: Gaviiformes	Suborder: Xenarthra
Order: *Proanura	Order: Colymbiformes	Order: Pholidota
Order: Salientia	Suborder: Pterocletes	Cohort: Glires
Suborder: Amphicoela	Suborder: Columbidae	Order: Lagomorpha
Suborder: Opisthocoela	Order: Procellariiformes	Order: Rodentia
Suborder: Anomocoela	Order: Sphenisciformes	Suborder: Sciuromorpha
Suborder: Procoela	Order: Pelecaniformes	Suborder: Myomorpha
Suborder: Diplasiocoela	Suborder: Phaethontes	Suborder: Hystricomorpha
Subclass: *Lepospondyli	Suborder: Pelecani	Cohort: Mutica
Order: *Aistopoda	Suborder: Fregatae	Order: Cetacea
Order: *Nectridia	Suborder: Odontopteryges	Suborder: *Archaeoceti
Order: *Microsauria	Order: Ciconiiformes	Suborder: Odontoceti
Order: Caudata	Suborder: Ardeinae	Suborder: Mysticeti
Suborder: Cryptobranchioidea	Suborder: Balaenicipites	Cohort: Ferungulata
Suborder: Ambystomoidea	Suborder: Ciconiae	Superorder: Ferae
Suborder: Salamandriodea	Suborder: Phoenicopteriformes	Order: Carnivora
Suborder: Proteidea	Order: Anseriformes	Suborder: *Creodonta
Order: Apoda	Suborder: Anhimae	Suborder: Fissipeda
Class: Reptilia	Suborder: Anseres	Suborder: Pinnipedia
Subclass: Anapsida	Order: Falconiformes	Superorder: *Protungulata
Order: *Cotylosauria	Suborder: Cathartae	Order: *Condylarthra
Suborder: *Captorhinomorpha	Suborder: Falcones	Order: *Litopterna
Suborder: *Diadectomorpha	Order: Galliformes	Order: *Notoungulata
Order: Chelonina	Suborder: Galli	Suborder: *Notioprogonia
Suborder: *Eunotosauria	Suborder: Opisthocomi	Suborder: *Toxodonta
Suborder: *Amphichelydia	Order: Musophagi	Suborder: *Typotheria
Suborder: Athecae	Order: Gruiformes	Suborder: *Hegetotheria
Suborder: Thecophora	Suborder: Mesoenatides	Order: *Astrapotheria
Subclass: *Ichthyopterygia	Suborder: Turnices	Suborder: *Trigonostylopoidea
Subclass: *Synaptosauria	Suborder: Grues	Suborder: *Astrapotherioidea
Order: *Protosauria	Suborder: Heliornithes	Order: Tubulidentata
Order: *Sauropterygia	Suborder: Rhynchoti	Superorder: Paenungulata
Suborder: *Nothosauria	Suborder: Eurypygae	Order: *Pantodonta
Suborder: *Plesiosauria	Suborder: *Phororhaci	Order: *Dinocerata
Suborder: *Placodontia	Suborder: Cariamae	Order: *Pyrotheria
Subclass: Lepidosauria	Suborder: Otides	Order: Proboscidea
Order: *Eosuchia	Order: *Diatrymiformes	Suborder: *Moeritherioidea
Suborder: *Younginiformes	Order: Charadriiformes	Suborder: Elephantioidea
Suborder: *Choristodera	Suborder: Charadrii	Suborder: *Deinotherioidea
Suborder: *Thalattosauria	Suborder: Lari	Suborder: *Barytherioidea
Suborder: *Acrosauria	Suborder: Alcae	Order: *Embrithopoda
Order: Rhynchocephalia	Order: Psittaciformes	Order: Hyracoidea
Order: Squamata	Order: Cuculiformes	Order: Sirenia
Suborder: Lacertilia	Order: Strigiformes	Suborder: Trichechiformes
Suborder: Serpentes	Order: Caprimulgiformes	Suborder: *Desmostyliiformes
Subclass: *Archosauria	Suborder: Steatornithes	Superorder: Mesaxonia
Order: *Thecodontia	Suborder: Caprimulgi	Order: Perissodactyla
Suborder: *Pseudosuchia	Order: Apodiformes	Suborder: Hippomorpha
Suborder: *Phytosauria	Suborder: Micropodi	Suborder: Ceratomorpha
Order: Crocodilia	Suborder: Trochili	Superorder: Paraxonia
Suborder: *Protosuchia	Order: Coliiformes	Order: Artiodactyla
Suborder: *Sebecosuchia	Order: Trogoniformes	Suborder: Suiformes
Suborder: *Mesosuchia	Order: Coraciiformes	Suborder: Tylopoda
Suborder: Eusuchia	Suborder: Alcedines	Suborder: Ruminantia

APPENDIX II. TAXONOMIC CLASSIFICATION: PLANTS
 Classification adapted from that of Engler, A., and Diels, L. Roman numerals refer to divisions.

Part I: PLANT KINGDOM: MAJOR GROUPS		
I. SCHIZOPHYTA (Bacteria)	Order: Entomophthorales	Order: Hydropteridales
Class: Schizomycetes	Order: Endogonales	XV. EMBRYOPHYTA SIPHONOGAMA
Order: Eubacteria	Order: Basidiobolales	(Phanerogamae)
Order: Thiobacteria	Class: Ascomycetes	XVa. GYMNOSPERMAE (Conifers and their
Class: Schizophyceae	Order: Spermophthorales	allies)
II. MYXOMYCETES (Slime molds)	Order: Euscales	Class: Cycadofilicales
Order: Hydromyces	Order: Laboulbeniales	Class: Cycadales
Order: Exosporales	Class: Protomycetes	Class: Bennettiales
Order: Cribbariales	Class: Basidiomycetes	Class: Ginkgoales
Order: Enteridiales	Subclass: Hemibasidii	Class: Cordaitales
Order: Liceales	Order: Ustilaginales	Class: Coniferae
Order: Stemonitales	Order: Uredinales	Class: Gnetales
Order: Physarales	Subclass: Eubasidii	XVb. ANGIOSPERMAE (Flowering plants)
Order: Margaritales	Order: Protobasidiomycetes	Class: Monocotyledoneae
Order: Trichiales	Order: Autobasidiomycetes	Order: Pandanales
III. FLAGELLATAE (Flagellates)	Supplement a ¹ : Fungi imperfecti	Order: Helobiae
Order: Pantostomatales	Supplement b ¹ : Lichenes	Order: Triuridales
Order: Distomatales	Subclass: Phycolichenes	Order: Glumiflorae
Order: Protomastigales	Subclass: Ascolichenes	Order: Principes
Order: Chrysomonadales	Order: Pyrenocarpeae	Order: Synanthae
Order: Cryptomonadales	Order: Gymnocarpeae	Order: Spathiflorae
Order: Chloromonadales	Subclass: Basidiolichenes	Order: Farinosae
Order: Euglenales	XIV. ARCHEGONIATAE	Order: Liliiflorae
IV. DINOFLAGELLATAE	XIVa. BRYOPHYTA (Mosses, liverworts)	Order: Scitamineae
Class: Adiniferidae	Class: Hepaticae	Order: Microspermae
Order: Athecatales	Order: Marchantiales	Class: Dicotyledoneae
Order: Thecatales	Order: Anthocerotales	Subclass: Archichlamydeae
Class: Diniferidae	Order: Jungermanniales	Order: Verticillatae
Order: Gymnodiniales	Class: Musci	Order: Piperales
Order: Peridinales	Subclass: Sphagnales	Order: Hydrostachyales
V. SILICOFLAGELLATAE	Subclass: Andreaeales	Order: Salicales
Order: Siphonostemales	Subclass: Bryales	Order: Garryales
Order: Stereotestales	Order Group: Eubryinales	Order: Myricales
VI. HETEROCONTAE	Order: Fissidentales	Order: Balanopsidales
VII. BACILLARIOPHYTA (Diatoms)	Order: Dicranales	Order: Leitneriales
Class: Centricae	Order: Pottiales	Order: Juglandales
Class: Pennales	Order: Grinniales	Order: Julianiales
VIII. CONJUGATAE (Green algae)	Order: Funariales	Order: Batidales
IX. CHLOROPHYCEAE (Blue-green algae)	Order: Schistostegales	Order: Fagales
Class: Protococcales	Order: Tetraphidales	Order: Urticales
Order: Volvocales	Order: Eubryales	Order: Podostemonales
Order: Euprotococcales	Order: Isobryales	Order: Proteales
Class: Ulotrichales	Order: Hookeriales	Order: Santalales
Class: Siphonocladales	Order: Hypnobryales	Order: Aristolochiales
Class: Siphonales	Order Group: Buxbaumiinales	Order: Balanophorales
X. CHAROPHYTA (Yellow-green algae)	Order: Buxbaumiiales	Order: Polygonales
XI. PHAEOPHYCEAE (Brown algae)	Order Group: Polytrichinales	Order: Centrospermae
Order: Ectocarpales	Order: Polytrichales	Order: Ranales
Order: Sphacelariales	Order: Dawsoniales	Order: Rhoadales
Order: Cutleriales	XIVb. PTERIDOPHYTA (Ferns and their allies)	Order: Sarraceniales
Order: Dictyotales	Class: Psilophytinae	Order: Rosales
Order: Laminariales	Class: Articulatae	Order: Pandales
Order: Tilopteridales	Subclass: Irotoarticulatales	Order: Geraniales
Order: Fucales	Subclass: Sphenophyllales	Order: Sapindales
XII. RHODOPHYCEAE (Red algae)	Subclass: Cheirostrobales	Order: Rhamnales
Class: Bangiales	Subclass: Pseudoborniales	Order: Malvales
Class: Florideae	Subclass: Equisetales	Order: Parietales
Order: Nemalionales	Order: Euequisetales	Order: Opuntiales
Order: Gelidiales	Order: Calamitales	Order: Myrtiflorae
Order: Cryptonemiales	Class: Lycopodiinae	Order: Umbelliflorae
Order: Gigartinales	Order: Lycopodiales	Subclass: Metachlamydeae
Order: Rhodymeniales	Order: Selaginellales	Order: Diapensiales
Order: Ceramiales	Suborder: Selaginellineae	Order: Ericales
XIII. EUMYCETES (Fungi)	Suborder: Lepidophytineae	Order: Primulales
Class: Phycomycetes	Class: Psilotinae	Order: Plumbaginales
Subclass: Oomycetes	Class: Isoetinae	Order: Ebenales
Order: Monoblepharidales	Class: Filicinae	Order: Convolvales
Order: Saprolegniales	Subclass: Eusporangiateae	Order: Tubiflorae
Order: Ancylistales	Order: Ophioglossales	Order: Plantaginales
Order: Peronosporales	Order: Marattiales	Order: Rubiales
Subclass: Zygomycetes	Subclass: Leptosporangiateae	Order: Cucurbitales
Order: Mucorales	Order: Euillicales	Order: Campanulatae
Part II: PHANEROGAMAE: FAMILIES		
XV. EMBRYOPHYTA SIPHONOGAMA	Family: Podocarpaceae	Family: Pandanaceae
XVa. GYMNOSPERMAE (Conifers and their	Family: Araucariaceae	Family: Sparganiaceae
allies)	Family: Cephalotaxaceae	Order: Helobiae
Class: Cycadofilicales	Family: Pinaceae	Suborder: Potamogetonineae
Class: Cycadales	Family: Taxodiaceae	Family: Aponogetonaceae
Family: Cycadaceae	Family: Cupressaceae	Family: Potamogetonaceae
Class: Bennettiales	Class: Gnetales	Family: Najadaceae
Family: Bennettitaceae	Family: Ephedraceae	Suborder: Scheuchzerineae
Class: Ginkgoales	Family: Welwitschiaceae	Family: Scheuchzeriaceae
Family: Ginkgoaceae	Family: Gnetales	Suborder: Alismatineae
Class: Cordaitales	XVb. ANGIOSPERMAE (Flowering plants)	Family: Alismataceae
Family: Cordaitaceae	Class: Monocotyledoneae	Suborder: Butomineae
Class: Coniferae	Order: Pandanales	Family: Butomaceae
Family: Taxaceae	Family: Typhaceae	Family: Hydrocharitaceae

/1/ Supplement to classes Ascomycetes and Protomycetes.

APPENDIX II. TAXONOMIC CLASSIFICATION: PLANTS (Continued)

Part II: PHANEROGAMAE: FAMILIES (Continued)

Order: Triuridales	Family: Urticaceae	Family: Myrothamnaceae
Family: Triuridaceae	Order: Podostemonales	Family: Bruniaceae
Order: Glumiflorae	Family: Podostemonaceae	Family: Hamamelidaceae
Family: Gramineae	Order: Proteales	Family: Roridulaceae
Family: Cyperaceae	Family: Proteaceae	Family: Eucommiaceae
Order: Principes	Order: Santalales	Suborder: Rosineae
Family: Palmae	Suborder: Santalaceae	Family: Platanaceae
Order: Synanthae	Family: Olacaceae	Family: Crossosomataceae
Family: Cyclanthaceae	Family: Opiliaceae	Family: Rosaceae
Order: Spathiflorae	Family: Octoknemataceae	Family: Connaraceae
Family: Araceae	Family: Grubbiaceae	Family: Leguminosae
Family: Lemnaceae	Family: Santalaceae	Order: Pandales
Order: Farinosae	Family: Myzodendraceae	Family: Pandaceae
Suborder: Flagellariineae	Suborder: Lorantheae	Order: Geraniales
Family: Flagellariaceae	Family: Lorantheae	Suborder: Geraniaceae
Suborder: Enantioblastae	Order: Aristolochiales	Family: Oxalidaceae
Family: Restionaceae	Family: Aristolochiaceae	Family: Geraniaceae
Family: Centrolepidaceae	Family: Rafflesiaceae	Family: Tropaeolaceae
Family: Mayacaceae	Family: Hydnoraceae	Family: Linaceae
Family: Xyridaceae	Order: Balanophorales	Family: Erythroxylaceae
Family: Eriocaulaceae	Family: Balanophoraceae	Family: Zygophyllaceae
Suborder: Bromeliineae	Order: Polygonales	Family: Cneoraceae
Family: Thurniaceae	Family: Polygonaceae	Family: Rutaceae
Family: Rapateaceae	Order: Centrospermae	Family: Simarubaceae
Family: Bromeliaceae	Suborder: Chenopodiineae	Family: Burseraceae
Suborder: Commelinineae	Family: Chenopodiaceae	Family: Meliaceae
Family: Commelinaceae	Family: Amaranthaceae	Family: Akariaceae
Suborder: Pontederiineae	Suborder: Phytolaccineae	Suborder: Malpighiineae
Family: Pontederiaceae	Family: Nyctaginaceae	Family: Malpighiaceae
Family: Cyanastraceae	Family: Phytolaccaceae	Family: Trigoniaceae
Suborder: Philodryneae	Family: Gyrostemonaceae	Family: Vochysiaceae
Family: Philodryceae	Family: Achatocarpaceae	Suborder: Polygalineae
Order: Liliiflorae	Family: Aizoaceae	Family: Tremandraceae
Suborder: Juncineae	Suborder: Portulacineae	Family: Polygalaceae
Family: Juncaceae	Family: Portulacaceae	Suborder: Dichapetalineae
Suborder: Liliineae	Family: Basellaceae	Family: Dichapetalaceae
Family: Stemonaceae	Suborder: Caryophyllineae	Suborder: Callitrichineae
Family: Liliaceae	Family: Caryophyllaceae	Family: Callitrichaceae
Family: Haemodoraceae	Order: Ranales	Order: Sapindales
Family: Amaryllidaceae	Suborder: Nymphaeinae	Suborder: Buxineae
Family: Velloziaceae	Family: Nymphaeaceae	Family: Buxaceae
Family: Taccaceae	Family: Ceratophyllaceae	Suborder: Empetrineae
Family: Dioscoreaceae	Suborder: Trochodendrineae	Family: Empetraceae
Suborder: Iridineae	Family: Trochodendraceae	Suborder: Coriariineae
Family: Iridaceae	Family: Cercidiphyllaceae	Family: Coriariaceae
Order: Scitamineae	Suborder: Ranunculineae	Suborder: Limnanthineae
Family: Musaceae	Family: Ranunculaceae	Family: Limnanthaceae
Family: Zingiberaceae	Family: Lardizabalaceae	Suborder: Anacardiineae
Family: Cannaceae	Family: Berberidaceae	Family: Anacardiaceae
Family: Marantaceae	Family: Menispermaceae	Suborder: Celastrineae
Order: Microspermae	Suborder: Magnoliineae	Family: Cyrillaceae
Suborder: Burmanniineae	Family: Magnoliaceae	Family: Pentaphylacaceae
Family: Burmanniaceae	Family: Himantandraceae	Family: Corynocarpaceae
Suborder: Gynandreae	Family: Calycanthaceae	Family: Agufoliaceae
Family: Orchidaceae	Family: Lactoridaceae	Family: Celastraceae
Class: Dicotyledoneae	Family: Anonaceae	Family: Hippocrateaceae
Subclass: Archichlamydeae	Family: Eupomatiaceae	Family: Salvadoraceae
Order: Verticillatae	Family: Myristicaceae	Family: Stackhouseiaceae
Family: Casuarinaceae	Family: Gomortegaceae	Family: Staphyleaceae
Order: Piperales	Family: Monimiaceae	Suborder: Icacinaceae
Family: Saururaceae	Family: Lauraceae	Family: Icacinaceae
Family: Piperaceae	Family: Hernandiaceae	Suborder: Sapindineae
Family: Chloranthaceae	Order: Rhoeadales	Family: Aextoxicaceae
Order: Hydrostachyales	Suborder: Rhoeadineae	Family: Aceraceae
Family: Hydrostachyaceae	Family: Papaveraceae	Family: Hippocastanaceae
Order: Salicales	Suborder: Cappariidaceae	Family: Sapindaceae
Family: Salicaceae	Family: Cappariidaceae	Suborder: Sabiineae
Order: Garryales	Family: Cruciferae	Family: Sabiaceae
Family: Garryaceae	Family: Tovariaceae	Suborder: Melianthineae
Order: Myricales	Suborder: Resedineae	Family: Melianthaceae
Family: Myricaceae	Family: Resedaceae	Suborder: Didiereineae
Order: Balanopsidales	Suborder: Moringineae	Family: Didiereaceae
Family: Balanopsidaceae	Family: Moringaceae	Suborder: Balsaminineae
Order: Leitneriales	Suborder: Bretschneiderineae	Family: Balsaminaceae
Family: Leitneriaceae	Family: Bretschneideraceae	Order: Rhamnales
Order: Juglandales	Order: Sarraceniales	Family: Rhamnaceae
Family: Juglandaceae	Family: Sarracenaceae	Family: Vitaceae
Order: Julianiales	Family: Nepenthaceae	Order: Malvales
Family: Julianiaceae	Family: Droseraceae	Suborder: Elaeocarpaceae
Order: Batidales	Order: Rosales	Family: Elaeocarpaceae
Family: Batidaceae	Suborder: Saxifragineae	Suborder: Chlaenineae
Order: Fagales	Family: Crassulaceae	Family: Chlaenaceae
Family: Betulaceae	Family: Cephalotaceae	Suborder: Malvineae
Family: Fagaceae	Family: Saxifragaceae	Family: Tiliaceae
Order: Urticales	Family: Pittosporaceae	Family: Malvaceae
Family: Ulmaceae	Family: Byblidaceae	Family: Bombacaceae
Family: Rhoipteleaceae	Family: Brunelliaceae	Family: Sterculiaceae
Family: Moraceae	Family: Cunoniaceae	Suborder: Scytopetalineae

APPENDIX II. TAXONOMIC CLASSIFICATION: PLANTS (Concluded)

Part II: PHANEROGAMAE: FAMILIES (Concluded)		
Family: Scytopetalaceae	Family: Heteropyxidaceae	Family: Desfontaineaceae
Order: Parietales	Family: Sonneratiaceae	Family: Loganiaceae
Suborder: Theineae	Family: Crypteroniaceae	Family: Gentianaceae
Family: Dilleniaceae	Family: Punicaceae	Family: Apocynaceae
Family: Actinidiaceae	Family: Lecythidaceae	Family: Asclepiadaceae
Family: Eucryphiaceae	Family: Rhizophoraceae	Order: Tubiflorae
Family: Medusagynaceae	Family: Nyssaceae	Suborder: Convolvulineae
Family: Ochnaceae	Family: Alangiaceae	Family: Convolvulaceae
Family: Strasburgeriaceae	Family: Combretaceae	Family: Polemoniaceae
Family: Caryocaraceae	Family: Myrtaceae	Family: Fouquieriaceae
Family: Marcgraviaceae	Family: Melastomataceae	Suborder: Lennoineae
Family: Quinaceae	Family: Hydrocaryaceae	Family: Lennoaceae
Family: Theaceae	Family: Oenotheraceae	Suborder: Boraginaceae
Family: Guttiferae	Family: Halorrhagaceae	Family: Hydrophyllaceae
Family: Diptercarpaceae	Suborder: Hippuridaceae	Family: Boraginaceae
Suborder: Tamaricaceae	Family: Hippuridaceae	Suborder: Verbenaceae
Family: Elatinaceae	Family: Thelygonaceae	Family: Verbenaceae
Family: Frankeniaceae	Suborder: Cynomoriaceae	Family: Labiatae
Family: Tamaricaceae	Family: Cynomoriaceae	Suborder: Solanaceae
Suborder: Cistaceae	Order: Umbelliflorae	Family: Nolanaceae
Family: Cistaceae	Family: Araliaceae	Family: Solanaceae
Family: Bixaceae	Family: Umbelliferae	Family: Scrophulariaceae
Suborder: Cochlospermaceae	Family: Cornaceae	Family: Bignoniaceae
Family: Cochlospermaceae	Subclass: Metachlamydeae	Family: Pedaliaceae
Suborder: Flacourtiaceae	Order: Diapensiaceae	Family: Martyniaceae
Family: Canellaceae	Family: Diapensiaceae	Family: Orobanchaceae
Family: Violaceae	Order: Ericales	Family: Gesneriaceae
Family: Flacourtiaceae	Subclass: Ericineae	Family: Columelliaceae
Family: Stachyuraceae	Family: Clethraceae	Family: Lentibulariaceae
Family: Turneraceae	Family: Pirolaceae	Family: Globulariaceae
Family: Malesherbiaceae	Family: Ericaceae	Suborder: Acanthineae
Family: Passifloraceae	Subclass: Epacridineae	Family: Acanthaceae
Family: Achariaceae	Family: Epacridaceae	Suborder: Myoporineae
Suborder: Papayineae	Order: Primulales	Family: Myoporaceae
Family: Caricaceae	Family: Theophrastaceae	Suborder: Phrymaceae
Suborder: Loasineae	Family: Myrsinaceae	Family: Phrymaceae
Family: Loasaceae	Family: Primulaceae	Order: Plantaginales
Suborder: Datisceae	Order: Plumbaginaceae	Family: Plantaginaceae
Family: Datisceae	Family: Plumbaginaceae	Order: Rubiales
Suborder: Begoniaceae	Order: Ebenales	Family: Rubiaceae
Family: Begoniaceae	Suborder: Sapotaceae	Family: Caprifoliaceae
Suborder: Ancistrocladaceae	Family: Sapotaceae	Family: Adoxaceae
Family: Ancistrocladaceae	Family: Hoplestigmataceae	Family: Valerianaceae
Order: Opuntiales	Suborder: Diospyrineae	Family: Dipsacaceae
Family: Cactaceae	Family: Ebenaceae	Order: Cucurbitales
Order: Myrtiflorae	Family: Didymanthaceae	Family: Cucurbitaceae
Suborder: Thymelaeaceae	Family: Symplocaceae	Order: Campanulatae
Family: Geissolomataceae	Family: Styracaceae	Family: Campanulaceae
Family: Penaeaceae	Family: Lissocarpaceae	Family: Goodeniaceae
Family: Oliniaceae	Order: Contortae	Family: Brunoniaceae
Family: Thymelaeaceae	Suborder: Oleineae	Family: Stylidiaceae
Family: Elaeagnaceae	Family: Oleaceae	Family: Calyceraceae
Suborder: Myrtineae	Suborder: Gentianeae	Family: Compositae
Family: Lythraceae		

APPENDIX III: ESTIMATED NUMBER OF SPECIES: ANIMAL, PLANT KINGDOM

Group	Number of Species ¹	Group	Number of Species ¹	Group	Number of Species ¹
Animal Kingdom		Animal Kingdom (concluded)		Plant Kingdom (concluded)	
1 Protozoa	15,000	27 Chordata	60,000	49 Eumycophyta (concluded)	
2 Porifera	5,000	28 Tunicata	700	50 Deuteromycetes	24,000
3 Coelenterata	10,000	29 Leptocarida	30	51 Lichenes	15,500
4 Ctenophora	100	Vertebrata		52 Bryophyta	23,820
5 Platyhelminthes	6,000	30 Pisces	40,000 ⁴	53 Hepaticae	8,500
6 Nemertea	500	31 Amphibia	2,769 ⁵	54 Anthocerotae	320
7 Nemathelminthes	5,000	32 Reptilia	6,959 ⁵	55 Musci	15,000
8 Trochelminthes	2,000	33 Aves	8,600 ⁶	56 Pteridophyta	11,280
9 Bryozoa	3,000	34 Mammalia	3,000-5,000 ⁷	57 Psilotales	3
10 Brachiopoda	120			58 Lycopodiales	483
11 Phoronidea	15	35 Total	938,000 ⁸	59 Selaginellales	700
12 Chaetognatha	30			60 Isotales	64
13 Annelida	6,500	Plant Kingdom		61 Equisetales	32
14 Arthropoda	750,000	36 Thallophyta	106,965	62 Filicales	10,000
15 Crustacea	25,000	37 Chlorophyta	5,700	63 Spermatophyta	200,665
16 Arachnoidea	15,000	38 Euglenophyta	335	64 Gymnospermae	665
17 Onychophora	80	39 Pyrrophyta ⁹	1,000	65 Cycadales	100
18 Myriopoda	7,000	40 Chrysophyta ¹⁰	5,700	66 Ginkgoales	1
19 Insecta	700,000 ²	41 Phaeophyta	900	67 Coniferae	520
20 Mollusca	70,000 ³	42 Cyanophyta	1,400	68 Gnetales	44
21 Echinodermata	5,000	43 Rhodophyta	2,500	69 Angiospermae	200,000
22 Crinoidea	635	44 Myxomycetes	430	70 Monocotyledones	34,000
23 Asteroidea	1,500	45 Eumycophyta	73,500	Dicotyledones	166,000
24 Ophiuroidea	1,500	46 Phycomycetes	1,500		
25 Echinoidea	771	47 Ascomycetes	25,000		
26 Holothurioidae	600	48 Basidiomycetes	23,000		

/1/ Exclusive of lower classification (subspecies, etc.), unless otherwise indicated. /2/ Estimated number of forms (species, subspecies, etc.), 900,000. /3/ Estimated number of forms, 100,000. /4/ Value includes "fish-like" vertebrates (Cyclostomata and Elasmobranchii). /5/ Applicable to number of forms. /6/ Estimated number of forms, 32,000. /7/ Estimated number of forms 20,000. /8/ Incomplete, recent estimates not available. /9/ Including Cryptophyceae, Desmokontae and Dinophyceae. /10/ Including Heterokontae and Chrysophyceae.

APPENDIX IV: SYMBOLS, UNITS, CONSTANTS, AND CONVERSION FACTORS

Although many of the values and symbols listed here may not be used as such in the Handbook, they will help the user translate values into units more applicable to his field, or to make a physical-chemical-biological correlation of data. Some of the tables include definitions and conversion factors which may not be listed here. In several instances two or more units of measurement may have the same symbol (e.g., M=mole; M=million); however, the possibility of confusion is remote because of the difference in the subject material where the units are applicable. The singular and plural forms of abbreviations are the same.

ABBREVIATIONS AND SYMBOLS USED IN THE HANDBOOK

mi = mile	lb = pound	yr = year	ev = electron volt
yd = yard	oz = ounce	mo = month	sp gr = specific gravity
ft = foot	kg = kilogram	wk = week	BP = boiling point
in. = inch	g = gram	da = day	MP = melting point
km = kilometer	dg = decigram	hr = hour	[α] _D = optical rotation
hm = hectometer	cg = centigram	min = minute	MW = molecular weight
m = meter	mg = milligram	sec = second	♂ = male
dm = decimeter	μg = microgram	msec = millisecond	♀ = female
cm = centimeter	gal = gallon	Cal = Calorie (kilocalorie)	mEq = milliequivalent
mm = millimeter	qt = quart	cal = calorie (gram calorie)	atm = atmosphere
μ = micron (10 ⁻³ mm)	pt = pint	°F = degrees Fahrenheit	μ = micro- (10 ⁻⁶)
mμ = millimicron (10 ⁻⁶ mm)	kl = kiloliter	°C = degrees centigrade	m = milli- (10 ⁻³)
Å = angstrom unit	hl = hectoliter	M = mole	c = centi- (10 ⁻²)
μμ = millionth micron (10 ⁻⁹ mm)	L = liter	F = farad	k = kilo- (10 ³)
sq = square (e.g., sq m = square meter)	ml = milliliter	r = roentgen	M = mega- (10 ⁶)
cu = cubic (e.g., cu cm = cubic centimeter)	μl = microliter	c = curie	B = billion (10 ⁹)

SYSTEMS OF UNITS

In many tables units are indicated in relationship to other measurements, as, for example, calories per square centimeter per hour. As an expedient to conserve space, these are presented as cal/sq cm/hr. The slashes in such cases should always be interpreted as "per" rather than as fractional designations.

A. Mechanical

System	Length	Mass	Time	Force	Velocity	Acceleration	Torque	Pressure	Energy	Power	Momentum
Meter-Kilogram-Second	Meter (m)	Kilogram (kg)	Second (sec)	Newton (nt)	m/sec	m/sec ²	m·nt	nt/m ²	Joule	Watt	kg·m/sec
Centimeter-Gram-Second	Centimeter (cm)	Gram (g)	sec	Dyne	cm/sec	cm/sec ²	dyne·cm	dyne/cm ²	Erg	Erg/sec	g·cm/sec
Foot-Pound-Second	Foot (ft)	Pound (lb)	sec	Poundal (pd)	ft/sec	ft/sec ²	pd·ft	pd/ft	ft·pd	ft·pd/sec	ft·lb/sec

B. Electrical

System	Energy	Power	Current	Charge	Electric Potential	Resistance	Electric Intensity	Capacitance	Inductance
Meter-Kilogram-Second	Joule	Watt	Ampere	Coulomb	Volt	Ohm	Volt/meter	Farad	Henry
Electromagnetic	Erg	(Joule/sec)	Abampere	Abcoulomb	Abvolt	Abohm	Abvolt/cm	Abfarad	Abhenry
Electrostatic	Erg	Erg/sec	Statampere	Statcoulomb	Statvolt	Statohm	Statvolt/cm	Statfarad	Stathenry

SOME USEFUL CONSTANTS

Constant	Value	Reciprocal	Logarithm
1/4 π	0.7853981634	1.2732395447	1.8950898814
1/2 π	1.5707963268	0.6366197724	0.1961198770
π	3.1415926536	0.3183098862	0.4971498727
2π	6.2831853072	0.1591549431	0.7981798684
√π	1.7724538509	0.5641895835	0.2485749363
√2π	2.5066282746	0.3989422804	0.3990899342
√(1/2π)	1.2533141373	0.7978845608	0.0980599385
1/2 √π	0.8862269255	1.1283791671	1.9475449407
e	2.7182818285	0.3678794412	0.4342944819
e ²	7.3890560989	0.1353352832	0.8685889638
√2	1.4142135624	0.7071067812	0.1505149978
√3	1.7320508076	0.5773502692	0.2385606274
√10	3.1622776602	0.3162277660	0.5000000000
Log ₁₀ e	0.4342944819	2.3025850930	1.6377843113
Radian	57.2957795131°	0.0174532925	1.7581226324

Binomial Coefficients											
Value of n _x											
4	5	6	7	8	9	10	11	12	1	0	
1	1	1	1	1	1	1	1	1	1	0	
4	5	6	7	8	9	10	11	12	1	1	
6	10	15	21	28	36	45	55	66	2	2	
4	10	20	35	56	84	120	165	220	3	3	
1	5	15	35	70	126	210	330	495	4	4	
	1	6	21	56	126	252	462	792	5	5	
		1	7	28	84	210	462	924	6	6	
			1	8	36	120	330	792	7	7	
				1	9	45	165	495	8	8	
					1	10	55	220	9	9	
						1	11	66	10	10	
							1	12	11	11	
								1	12	12	

Speed of light in a vacuum; also, ratio of emu to esu of electric charge (c)	(2.99776±0.00004) x 10 ⁸ m/sec
Charge of an electron (e)	(1.6020±0.0002) x 10 ⁻¹⁹ coulomb
Faraday's constant; the charge transported by a gram atom of a univalent element (F)	(96,522±7) coulombs/mole
Avogadro's number; the number of molecules in a gram molecule or of atoms in a gram atom (N ₀)	(6.0251±0.0004) x 10 ²³
Standard atmospheric pressure (P ₀)	(101,324.6±0.4) nt/sq m
Freezing point of water on the absolute (Kelvin) scale (T ₀)	(273.16±0.02) °K
Density of mercury at STP	(13,595.04±0.06) kg/cu m
Atomic weight of oxygen, physical scale*	(16.00436±0.00009)
Volume of a mole of perfect gas at STP (V ₀)	(22,420.7±0.6) cu cm
Universal gas constant (R ₀)	(8,316.6±0.4) joules/kg·°K
Boltzmann's constant; gas constant per molecule (k)	(1.3803±0.0001) x 10 ⁻²³ joule/°K
Mass of atom of unit atomic weight, physical scale* (m ₁)	(1.6589±0.0014) x 10 ⁻²⁴ g
Mass of electron (m _e)	(9.103±0.008) x 10 ⁻²⁸ g
Mechanical equivalent of heat	(4185.5±0.4) joules/Cal
Gravitation constant (G)	(6.670±0.005) x 10 ⁻¹¹ nt·sq m/sq kg
Planck's (quantum) constant (h)	(6.623±0.001) x 10 ⁻³⁴ joule·sec

*An atomic weight of 16 for oxygen (as determined by chemical analysis) is the basis for the chemical scale of atomic weights. In the physical scale the value of 16 is assigned to the most abundant isotope of oxygen. Physical scale atomic weights are larger than those in the chemical scale by a ratio of 1.00027 to 1.

CONVERSION FACTORS

Units expressed in Column A, when multiplied by the accompanying factor in Column B, are converted to units expressed in Column C.

Column A	x	Column B	=	Column C	Column A	x	Column B	=	Column C
Abamperes		10.0000		amperes	Calorie (15°C) sec		6.3854×10^{33}		quanta
Abamperes		2.99796×10^{10}		statampere	Calories (15°C)/am-		0.011625		joules/abcoulomb
Abcoulombs		10.0000		coulombs (Abs.)	pere-hr				
Abcoulombs		2.99796×10^{10}		statcoulombs	Calories (15°C)/		41.850		joules/abcoulomb
Abcoulombs/kg		30577		statcoulombs/dyne	coulomb				
Abcoulombs/lb		6.7411×10^4		statcoulombs/dyne	Calories, gram (15°C)/		0.0022046		BTU (60°F)/°F
Abfarads		1.0000×10^9		farads (Abs.)	°C				
Abfarads		1×10^{15}		microfarads	Calories, gram (15°C)/		4.185		joules/°C
Abfarads		8.98776×10^{20}		statfarads	°C				
Abhenries		1.0000×10^{-9}		henries (Abs.)	Calories, gram (mean)/		1.8		BTU (mean)/lb
Abhenries		1×10^{-6}		millihenries	g				
Abhenries		1.11263×10^{-21}		stathenries	Calories, gram (mean)/		1		BTU (60°F)/lb/°F
Abmhms/cu cm		1000		megmhms/cu cm	g/°C				
Abmhms/cu cm		1.00052×10^9		mhos, International/cu	Calories, gram (mean)/		4.186		joules/g/°C
				cm	g/°C				
Abmhms/cu cm		166.2		mhos/mil ft	Calorie (15°C) sec/N ₀ *		1.0535×10^{10}		quanta
Abohms		1×10^{-15}		megohms	Calories, kg (mean)		3.9685		BTU (mean)
Abohms		0.001		microhms	Calories, kg (mean)		1000		gram calories, (mean)
Abohms		1.0000×10^{-9}		ohms (Abs.)	Calories, kg (mean)		4.186×10^{10}		ergs
Abohms		1.11263×10^{-21}		statohms	Calories, kg (mean)		3087.4		ft lb
Abvolts		0.010000		microvolts	Calories, kg (mean)		4.2686×10^7		g cm
Abvolts		3.33560×10^{-1}		statvolts	Calories, kg (mean)		0.0015593		horse power hr
Abvolts		1.0000×10^{-8}		volts (Abs.)	Calories, kg (mean)		4186		joules
Abvolts/cm		1.0000×10^{-8}		volts (Abs.)/cm	Calories, kg (mean)		426.85		kg m
Abvolts/°F		0.018000		microvolts/°C	Calories, kg (mean)		0.0011628		KW hr
Abvolts/in.		3.9370×10^{-9}		volts (Abs.)/cm	Calories, kg (mean)/		51.457		ft lb/sec
Acres (U. S.)		40.46873		ares (sq. dekameters)	min				
Acres (U. S.)		0.4046873		hectares (sq. hectom-	Calories, kg (mean)/		0.093558		horse power
				eters)	min				
Acres (U. S.)		43560		sq ft	Calories, kg (mean)/		69.769		watts
Acres (U. S.)		4046.873		sq m	min				
Acres (U. S.)		0.0015625		sq mi	Calories, kg (mean)/sec		4.186		kilowatts
Acres (U. S.)		160		sq rods	Candles (International)		1.0000		lumens (International)/
Acres (U. S.)		4840		sq yd					steradian
Amperes (Abs.)		0.1		abamperes	Candle power		12.566		lumens
Amperes (Abs.)		1.00007		amperes (International)	(spherical)				
Amperes (Abs.)		1.0363×10^{-5}		faradays/sec	Candles/sq cm		3.1416		lamberts
Amperes (Abs.)		2.99796×10^9		statamperes	Candles/sq in.		0.48695		lamberts
Ampere-hr (Abs.)		3600.0		coulombs (Abs.)	Centigrade thermal		1898.3		joules (Abs.)
Angstrom units		3.937×10^{-9}		inches	unit (15°C)				
Angstrom units		1×10^{-10}		meters	Centimeters		1×10^8		angstrom units
Angstrom units		100		micro-microns	Centimeters		0.032808		feet (British or U.S.)
Angstrom units		1×10^{-4}		microns	Centimeters		0.393700		inches (U.S.)
Angstrom units		0.1		milli-microns	Centimeters		10000		microns
Atmospheres		1.0133		bars	Centimeters		393.70		mils
Atmospheres		76		cm Hg at 0°C	Centimeters		0.01093611		yards (U. S.)
Atmospheres		1.01325×10^6		dynes/cm ²	Cm Hg at 0°C		0.013158		atmospheres
Atmospheres		33.899		ft of water at 39.1°F	Cm Hg at 0°C		1.33322×10^4		dynes/sq cm
Atmospheres		1033.3		g/sq cm	Cm Hg at 0°C		0.44604		ft of water at 39.1°F
Atmospheres		29.921		in. Hg at 32°F	Cm Hg at 0°C		135.95		kg/sq m
Atmospheres		10333		kg/sq m	Cm Hg at 0°C		27.845		lb/sq ft
Atmospheres		760000		microns of Hg	Cm Hg at 0°C		0.19337		lb/sq in.
Atmospheres		760		mm Hg	Centimeters/sec		1.9685		ft/min
Atmospheres		2116.32		lb/sq ft	Centimeters/sec		0.03600		km/hr
Atmospheres		14.696		lb/sq in.	Centimeters/sec		0.6000		m/min
Barrels (U.S., dry)		3.281		bushels	Centimeters/sec		0.02237		mi/hr
Barrels (U.S., dry)		7056		cu in.	Centimeters/sec		3.728×10^{-4}		mi/min
Barrels (U.S., dry)		0.11562		cu m	Centimeters/sec ²		0.036		km/hr/sec
Barrels (U.S., dry)		105.0		quarts (dry)	Centimeters/sec ²		0.02237		mi/hr/sec
Barrels (U.S., liquid)		0.11924		cu m	Circles		360		degrees
Barrels (U.S., liquid)		31.5		gallons	Circles		6.28319		radians
BTU		252		gram calories	Circular in.		5.0671		sq cm
BTU		25030		foot pounds	Circular in.		0.78540		sq in.
BTU		777.9		ft lb	Circular mm		0.78540		sq mm
BTU		3.929×10^{-4}		horse power hr	Circumferences		360		degrees
BTU		1055		joules	Circumferences		400		grades
Bushels (U.S., dry)		0.304785		barrels	Coulombs (Abs.)		0.1000		abcoulombs or electro-
Bushels (U.S., dry)		35239		cu cm					magnetic cgs units
Bushels (U.S., dry)		1.2444		cu ft	Coulombs (Abs.)		1.00010		coulombs (Internat-
Bushels (U.S., dry)		2150.42		cu in.					tional)
Bushels (U.S., dry)		0.035239		cu m	Coulombs (Abs.)		6.281×10^{18}		electronic charges
Bushels (U.S., dry)		0.35238329		hectoliters	Coulombs (Abs.)		2.99796×10^9		electrostatic cgs units
Bushels (U.S., dry)		35.238329		liters					or statcoulombs
Bushels (U.S., dry)		4		pecks	Coulombs (Internat-		0.99990		coulombs (Abs.)
Bushels (U.S., dry)/acre		0.870754		hectoliters/hectare	tional)				
Calories, g		3.968×10^{-3}		BTU	Coulombs/kg		3057.7		statcoulombs/dyne
Calories, g (mean)		0.001469		cu ft atm	Cubic cm		3.531445×10^{-5}		cu ft (U. S.)
Calories, g (mean)		99.334		foot-pounds	Cubic cm		0.061023		cu in.
Calories, g (mean)		3.0874		ft lb	Cubic cm		1.3079×10^{-6}		cu yd
Calories, g		1.5591×10^{-6}		horse power hr	Cubic cm		0.27053		drams (U.S., fluid)
Calories, g (15°C)		4.185		joules (Abs.)	Cubic cm		2.6417×10^{-4}		gal (U.S.)
Calories, g (mean)		0.42685		kg m	Cubic cm		9.9997×10^{-4}		liters
Calories, g (mean)		4.1311×10^{-2}		L-atm	Cubic cm		16.231		minims (U.S.)
Calories, g (mean)		0.0011628		watt hr	Cubic cm		0.033814		ounces (U.S., fluid)

* Avogadro's number.

CONVERSION FACTORS (Continued)

Column A	x	Column B	=	Column C	Column A	x	Column B	=	Column C
Cubic cm	0.0021134			pints (U.S., liquid)	Drams (avoirdupois)	27.34375			grains
Cubic cm	9.0808 x 10 ⁻⁴			quarts (U.S., dry)	Drams (avoirdupois)	1.771845			grams
Cubic cm	0.0010567			quarts (U.S., liquid)	Drams (avoirdupois)	0.0625			ounces (avoirdupois)
Cubic cm atm (normal)	0.101325			joules (Abs.)	Drams (avoirdupois)	0.056966146			ounces (troy)
Cubic cm/sec	0.0021186			cu ft/min	Drams (avoirdupois)	1/256			pounds (avoirdupois)
Cubic ft (U.S.)	28317			cu cm	Drams (avoirdupois)	0.0047471788			pounds (troy)
Cubic ft (U.S.)	1728			cu in.	Drams (U.S., fluid or apoth.)	3.6967			cu cm
Cubic ft (U.S.)	0.02831701			cu m					
Cubic ft (U.S.)	0.037037			cu yd	Drams (U.S., fluid or apoth.)	0.225570			cu in.
Cubic ft (U.S.)	7.481			gallons (U.S.)					
Cubic ft (U.S.)	28.316			liters	Drams (U.S., fluid or apoth.)	3.6966			milliliters
Cubic ft (U.S.)	25.714			quarts (U.S., dry)					
Cubic ft (U.S.)	29.922			quarts (U.S., liquid)	Drams (U.S., fluid or apoth.)	60			minims (U.S., fluid)
Cubic ft atm	680.74			gram calories (mean)					
Cubic ft atm	2116.3			ft lb	Drams (U.S., fluid or apoth.)	0.125			ounces (fluid)
Cubic ft atm	2869.4			joules (Abs.)					
Cubic ft atm	292.59			kg m	Dynes	0.015368			grains
Cubic ft atm	28.316			L atm	Dynes	0.00101972			grams
Cubic ft of water (60°F)	62.37			pounds	Dynes	2.2481 x 10 ⁻⁶			pounds
Cubic ft/min	472.0			cu cm/sec	Dyne-cm (torque)	1.0197 x 10 ⁻⁸			kg m
Cubic ft/min	0.1247			gal/sec	Dyne-cm (torque)	7.3757 x 10 ⁻⁸			lb ft
Cubic ft/min	0.4720			L/sec	Dyne-cm (torque)	8.8511 x 10 ⁻⁷			lb in.
Cubic ft/sec	2.2222			cu yd/min	Dynes/cm	1			ergs/sq cm
Cubic in. (U.S.)	4.65025 x 10 ⁻⁴			bushels (U.S.)	Dynes/cm	0.01			ergs/sq mm
Cubic in. (British)	16.3870253			cu cm	Dynes/cm	2.5901			mg/in.
Cubic in. (U.S.)	16.387162			cu cm	Dynes/cm	0.10197			mg/mm
Cubic in. (British)	5.7870 x 10 ⁻⁴			cu ft (British)	Dynes/sq cm	9.8692 x 10 ⁻⁷			atm
Cubic in. (U.S.)	5.78704 x 10 ⁻⁴			cu ft (U.S.)	Dynes/sq cm	2.9530 x 10 ⁻⁵			in. Hg at 32°F
Cubic in. (U.S.)	1.63871 x 10 ⁻⁵			cu m	Dynes/sq cm	4.0148 x 10 ⁻⁴			in. of water at 39.2°F (4°C.)
Cubic in. (U.S.)	2.143347 x 10 ⁻⁵			cu yards					kg/sq m
Cubic in. (U.S.)	4.43322			drams (fluid)	Dynes/sq cm	0.0101971			mm Hg
Cubic in. (U.S.)	0.0043290			gallons (U.S.)	Dynes/sq cm	7.5006 x 10 ⁻⁴			lb/sq ft
Cubic in. (U.S.)	0.0163868			liters	Dynes/sq cm	0.0020886			lb/sq in.
Cubic in. (U.S.)	0.5541			ounces (fluid) (U.S.)	Dynes/sq cm	1.4504 x 10 ⁻⁵			gauss (Abs.)
Cubic in. (U.S.)	0.00186010			pecks (U.S.)	Electromagnetic cgs unit of field strength	1.0000			
Cubic in. (U.S.)	0.0297616			pints (U.S., dry)	Electromagnetic cgs units of magnetic permeability	8.9916 x 10 ²⁰			electrostatic cgs units of magnetic permeability
Cubic in. (U.S.)	0.0148808			quarts (U.S., dry)	Electromagnetic cgs units of mass resistance	9.9948 x 10 ⁻⁶			ohm, International-meter-gram
Cubic in. (U.S.)	0.017316			quarts (U.S., liquid)					
Cubic km	1 x 10 ⁹			cu m	Electromagnetic cgs units of reluctance	1.0000			oersteds (Abs.)
Cubic m	28.3776			bushels (U.S.)					
Cubic m	1 x 10 ⁶			cu cm					
Cubic m	35.314445			cu ft (U.S.)					
Cubic m	61023			cu in.					
Cubic m	1.3079428			cu yd (U.S.)					
Cubic m	999.973			liters	Electronic charges	1.5921 x 10 ⁻²⁰			abcoulombs
Cubic m	2113.4			pints (U.S., liquid)	Electronic charges	1.5921 x 10 ⁻¹⁹			coulombs (Abs.)
Cubic m	1056.7			quarts (U.S., liquid)	Electronic charges	4.774 x 10 ⁻¹⁰			statcoulombs
Cubic mm	6.1023 x 10 ⁻⁵			cu in.	Electrons/kg	4.868 x 10 ⁻¹⁶			statcoulombs/dyne
Cubic mm	1 x 10 ⁻⁹			cu m	Electrostatic cgs units of field strength	3.33560 x 10 ⁻¹¹			gauss (Abs.)
Cubic mm	0.016231			minims (U.S.)					
Cubic yd	764559.45			cu cm	Ergs	9.4805 x 10 ⁻¹¹			BTU (mean)
Cubic yd (U.S.)	27			cu ft	Ergs	2.3889 x 10 ⁻⁸			gram calories (mean)
Cubic yd (U.S.)	46656			cu in.	Ergs	2.3889 x 10 ⁻¹¹			kg calories (mean)
Cubic yd (U.S.)	0.76455945			cu m	Ergs	7.3756 x 10 ⁻⁸			ft lb
Cubic yd (U.S.)	202.0			gallons (U.S.)	Ergs	0.00101972			g cm
Cubic yd	764.54			liters	Ergs	1 x 10 ⁻⁷			joules
Cubic yd (U.S.)	1616			pints (U.S., liquid)	Ergs	1.0197 x 10 ⁻⁸			kg m
Cubic yd (U.S.)	807.9			quarts (U.S., liquid)	Ergs/sec	5.6883 x 10 ⁻⁹			BTU (mean)/min
Days (mean solar)	24			hours (mean solar)	Ergs/sec	1.4333 x 10 ⁻⁹			kg calories (mean)/min
Days (mean solar)	1440			minutes (mean solar)	Ergs/sec	4.4254 x 10 ⁻⁶			ft lb/min
Days (mean solar)	86400			seconds (mean solar)	Ergs/sec	7.3756 x 10 ⁻⁸			ft lb/sec
Days (sidereal)	86164			seconds (mean solar)	Ergs/sec	1.3410 x 10 ⁻¹⁰			horse power
Degrees	0.00277778			circumferences	Ergs/sec	1 x 10 ⁻¹⁰			KW
Degrees	60			minutes	Ergs/sec	1 x 10 ⁻⁷			watts
Degrees	1/90			quadrants	Ergs/sq cm	1			dynes/cm
Degrees	0.0174533			radians	Ergs/sq cm	0.01			ergs/sq mm
Degrees	0.00277778			revolutions	Ergs/sq mm	100			dynes/cm
Degrees	3600			seconds	Ergs/sq mm	100			ergs/sq cm
Degrees/sec	0.1667			revolutions/min	Faradays	9.6500 x 10 ⁴			coulombs (Abs.)
Degrees/sec	0.002778			revolutions/sec	Faradays	9.6507 x 10 ⁴			coulombs (International)
Drams (apothecaries' or troy)	2.194286			drams (avoirdupois)	Faradays/kg	2.9507 x 10 ⁸			statcoulombs/dyne
Drams (apothecaries' or troy)	60			grains	Faradays/sec	96500			amperes (Abs.)
Drams (apothecaries' or troy)	3.8879351			grams	Farads (Abs.)	1 x 10 ⁻⁹			Abfarads
Drams (apothecaries' or troy)	0.1371429			ounces (avoirdupois)	Farads (Abs.)	1.00052			farads (International)
Drams (apothecaries' or troy)	0.125			ounces (troy)	Farads (Abs.)	1 x 10 ⁶			microfarads
Drams (troy)	2.5			pennyweights	Farads (Abs.)	8.98776 x 10 ¹¹			statfarads
Drams (apothecaries' or troy)	0.008571429			pounds (avoirdupois)	Farads (International)	0.99948			farads (Abs.)
Drams (apothecaries' or troy)	1/96			pounds (troy)	Fathoms	6			feet
Drams (avoirdupois)	0.4557292			drams (apothecaries' or troy)	Feet (U.S.)	30.48006096			centimeters
					Feet (U.S.)	0.3048006096			meters
					Feet (U.S.)	1.6447 x 10 ⁻⁴			miles (nautical)
					Feet (U.S.)	1.893939 x 10 ⁻⁴			miles (statute)
					Feet (U.S.)	473404			wave lengths of red line of cadmium atm
					Feet of water at 39.2°F (4°C.)	0.029499			
					Feet of water at 39.2°F (4°C.)	0.88265			in. Hg at 32°F (0°C.)

CONVERSION FACTORS (Continued)

Column A	Column B	Column C	Column A	Column B	Column C
Feet of water at 39.2°F (40°C.)	304.79	kg/sq m	Grams/sq cm	0.0142234	lb/sq in.
Feet of water at 39.2°F (40°C.)	0.43352	lb/sq in.	Gravity	980.665	cm/sec ²
Feet of water at 39.2°F (40°C.)	62.427	lb/sq ft	Gravity	32.174	ft/sec ²
Feet/min	0.508001	cm/sec	Hectares	2.471044	acres (U.S.)
Feet/min	0.01829	km/hr	Hectares	10,000	sq m
Feet/min	0.00508001	mi/sec	Hectares	11959.85	sq yd (U.S.)
Feet/min	0.011364	m/hr	Horse power	42.418	BTU (mean)/min
Feet/sec	1.0973	km/hr	Horse power	10.688	kg calories (mean)/min
Feet/sec	0.5921	knots/hr	Horse power	33,000	ft lb/min
Feet/sec	18.29	m/min	Horse power	550	ft lb/sec
Feet/sec	0.6818	mi/hr	Horse power	1.0139	horse power (metric)
Feet/sec	0.011364	mi/min	Horse power	0.74570	KW
Feet/sec ²	1.0973	km/hr/sec	Horse power	745.70	watts
Foot candles	10.764	lumens/sq m	Horse power (metric)	32549	ft lb/min
Foot pounds	0.32389	gram calories (mean)	Horse power (metric)	0.98632	horse power (U.S.)
Foot pounds	4.7253 x 10 ⁻⁴	cu ft atm	Horse power (metric)	75	kg m/sec
Foot pounds	1.35582 x 10 ⁷	ergs	Horse power hr	641.304	kg calories (mean)
Foot pounds	1.3825 x 10 ⁴	g cm	Horse power hr	1.9800 x 10 ⁶	ft lb
Foot pounds	5.0505 x 10 ⁻⁷	horse power hr	Horse power hr	2.6845 x 10 ⁶	joules (Abs.)
Foot pounds	1.35582	joules (Abs.)	Hours (mean solar)	2.7374 x 10 ⁵	kg m
Foot pounds	0.138255	kg m	Hours (mean solar)	0.7457	KW hr
Foot pounds	3.7662 x 10 ⁻⁷	KW hr	Inches (U.S.)	0.041667	days (mean solar)
Foot pounds	0.013381	L atm	Inches (U.S.)	0.0059524	weeks
Foot pounds/min	2.2597 x 10 ⁻⁵	KW	Inches (U.S.)	2.5400 x 10 ⁸	angstrom units
Foot pounds/sec	0.0018182	horse power	Inches (U.S.)	2.540005	centimeters
Foot pounds/sec	0.00135582	KW	Inches (U.S.)	1.57828 x 10 ⁻⁵	miles
Foot pounds/sec	1.35582	watts (Abs.)	Inches (U.S.)	39450.45	wave length of the red line of cadmium
Gallons (U.S.)	3785.4	cu cm	Inches Hg at 32°F	0.033421	atm
Gallons (U.S.)	0.13368	cu ft	Inches Hg at 32°F	3.38639 x 10 ⁴	dynes/sq cm
Gallons (U.S.)	231	cu in.	Inches Hg at 32°F	345.31	kg/sq m
Gallons (U.S.)	0.0037854	cu m	Inches Hg at 32°F	70.727	lb/sq ft
Gallons (U.S.)	0.004951	cu yd	Inches of water at 39.2°F (40°C)	0.0024583	atm
Gallons (U.S.)	3.78533	liters	Inches of water at 39.2°F (40°C)	2490.82	dynes/sq cm
Gallons (U.S.)	61440	minims	Inches of water at 39.2°F (40°C)	25.399	kg/sq m
Gallons (U.S.)	128	ounces (U.S., fluid)	Inches of water at 39.2°F (40°C)	5.2022	lb/sq ft
Gallons (U.S.)	8	pints (U.S., liquid)	Joules (Abs.)	9.480 x 10 ⁻⁴	BTU (mean)
Gallons (U.S.)	8.3378	pounds (avoirdupois) of water at 62°F (16.7°C)	Joules (Abs.)	0.23895	gram calories (mean)
Gallons (U.S.)	4	quarts (U.S., liquid)	Joules (Abs.)	0.23918	gram calories (20°C)
Gallons (U.S.) water/min	6.0086	tons water/24 hours	Joules (Abs.)	2.3889 x 10 ⁻⁴	kg calories (mean)
Gallons (U.S.)/min	8.0208	cu ft/hr	Joules (Abs.)	3.485 x 10 ⁻⁴	cu ft atm
Gallons (U.S.)/min	0.002228	cu ft/sec	Joules (Abs.)	1 x 10 ⁷	ergs
Gallons (U.S.)/min	0.06308	L/sec	Joules (Abs.)	0.73756	ft lb
Grains	63.5453	dynes	Joules (Abs.)	1.0197 x 10 ⁴	g cm
Grains	0.064798918	grams	Joules (Abs.)	3.72508 x 10 ⁻⁷	horse power hr
Grains	64.798918	milligrams	Joules (Abs.)	0.999680	joules (international)
Grains	0.0022857	ounces (avoirdupois)	Joules (Abs.)	0.101972	kg m
Grains	0.0020833	ounces (troy)	Joules (Abs.)	2.77778 x 10 ⁻⁷	KW hr
Grains	1/7000	pounds (avoirdupois)	Joules (Abs.)	0.0098689	L atm
Grains	1/5760	pounds (troy)	Joules/°C	5.2679 x 10 ⁻⁴	BTU (60°F)/°F
Grams	980.665	dynes	Joules/°C	0.23889	gram calories/°C
Grams	15.4324	grains	Joules/electron	6.2811 x 10 ¹⁹	joules/abcoumb
Grams	1 x 10 ⁶	micrograms	Joules/electron/°C	6.2811 x 10 ¹⁸	joules/coulombs/°C
Grams	1000	milligrams	Joules/faraday	1.0363 x 10 ⁻⁴	joules/abcoumb
Grams	0.0352739	ounces (avoirdupois)	Joules/faraday/°C	1.0363 x 10 ⁻⁵	joules/coulomb/°C
Grams	0.0321507	ounces (troy)	Joules/gram/°C	0.23889	gram calories (mean)/g/°C
Grams	0.00220462	pounds (avoirdupois)	Joule seconds	1.5258 x 10 ³³	quanta
Grams	0.00267923	pounds (troy)	Joule seconds/No*	2.5173 x 10 ⁹	quanta
Grams	1 x 10 ⁻⁶	tons (metric)	Kilograms	9.80665 x 10 ⁵	dynes
Gram centimeters	2.3427 x 10 ⁻⁵	gram calories (mean)	Kilograms	2.204622341	pounds (avoirdupois)
Gram centimeters	980.665	ergs	Kilograms	2.6792285	pounds (troy)
Gram centimeters	7.233 x 10 ⁻⁵	ft lb	Kilogram meters	0.00929667	BTU (mean)
Gram centimeters	9.80665 x 10 ⁻⁵	joules (Abs.)	Kilogram meters	2.3427	gram calories (mean)
Gram centimeters	1 x 10 ⁻⁵	kg m	Kilogram meters	0.0034177	cu ft atm
Gram centimeters/sec	9.80665 x 10 ⁻⁵	watts (Abs.)	Kilogram meters	9.80665 x 10 ⁷	ergs
Gram sq cm (moment of inertia)	2.37305 x 10 ⁻⁶	lb/sq ft	Kilogram meters	232.71	foot poundals
Gram sq cm (moment of inertia)	3.4172 x 10 ⁻⁴	lb/sq in.	Kilogram meters	7.2330	ft lb
Grams/cu cm	62.43	lb/cu ft	Kilogram meters	3.6529 x 10 ⁻⁶	horse power hr
Grams/cu cm	0.03613	lb/cu in.	Kilogram meters	2.72407 x 10 ⁻⁶	KW hr
Grams/cu cm	8.3454	lb/gal (U.S.)	Kilograms/m	0.67197	lb/ft
Grams/cu m	0.35757	grains/cu ft	Kilograms/sq cm	73.556	cm Hg at 0°C
Grams/L	58.417	grains/gal (U.S.)	Kilograms/sq cm	14.223	lb/sq in.
Grams/L	1000	parts per million	Kilograms/sq m	9.6777 x 10 ⁻⁵	atm
Grams/L	0.062427	lb/cu ft	Kilograms/sq m	98.0665	dynes/sq cm
Grams/L	8.345	lb/1000 gal (U.S.)	Kilograms/sq m	0.0032809	ft of water
Grams/ml	0.999973	g/cu cm	Kilograms/sq m	0.1	g/sq cm
Grams/sq cm	9.6784 x 10 ⁻⁴	atm	Kilograms/sq m	0.0028959	in. Hg
Grams/sq cm	980.665	dynes/sq cm	Kilograms/sq m	0.073556	mm Hg
Grams/sq cm	10	kg/sq m	Kilograms/sq m	0.204817	lb/sq ft
Grams/sq cm	0.73556	mm Hg at 0°C	Kilograms/sq mm	0.00142234	lb/sq in.
Grams/sq cm	2.04817	lb/sq ft	Kiloliters	9.80665 x 10 ⁷	dynes/sq cm
				35.317	cu ft

* Avogadro's number.

CONVERSION FACTORS (Continued)

Column A	x	Column B	=	Column C	Column A	x	Column B	=	Column C
Kilometers		3280.83		feet	Mhos, International/cu cm		0.99948		mhos (Abs.)/cu cm
Kilometers		0.539593		miles (nautical)	cm				
Kilometers		0.6213699495		miles (U.S.)	Microfarads		1×10^{-15}		abfarads
Kilometers		0.1		myriameters	Microns		1×10^4		angstrom units
Kilometers		1093.6		yards	Microns		1×10^{-4}		centimeters
Kilometers/hr		27.7778		cm/sec	Microns		3.937×10^{-5}		inches
Kilometers/hr		54.68		ft/min	Microns		0.001		millimeters
Kilometers/hr		0.9113		ft/sec	Microvolts/°F		1.8000		microvolts/°C
Kilometers/hr		0.5396		knots/hr	Miles (nautical)		6080.20		feet
Kilometers/hr		16.667		m/min	Miles (nautical)		1.85325		kilometers
Kilometers/hr		0.27778		m/sec	Miles (U.S., statute)		63360		inches
Kilometers/hr/sec		27.778		cm/sec ²	Miles (U.S., statute)		5280		feet
Kilometers/hr/sec		0.9113		ft/sec ²	Miles (U.S., statute)		1.609347219		kilometers
Kilometers/hr/sec		0.27778		m/sec ²	Miles/hr		44.7041		cm/sec
Kilometers/min		1666.7		cm/sec	Miles/hr		88		ft/min
Kilometers/min		37.2822		mi/hr	Miles/hr		1.4667		ft/sec
Kilowatt hours		3413.0		BTU (mean)	Miles/hr		0.8684		knots/hr
Kilowatt hours		8.6001×10^5		gram calories (mean)	Miles/hr		26.82		m/min
Kilowatt hours		2.6552×10^6		ft lb	Miles/hr/min		0.74507		cm/sec ²
Kilowatt hours		1.3410		horse power hr	Miles/hr/sec		44.704		cm/sec ²
Kilowatt hours		3.6000×10^6		joules (Abs.)	Miles/hr/sec		1.4667		ft/sec ²
Kilowatt hours		3.6709×10^5		kg m	Miles/hr/sec		0.44704		m/sec ²
Kilowatts		56.884		BTU (mean)/min	Miles/min		2682.2		cm/sec
Kilowatts		14.3334		kg calories (mean)/min	Miles/min		88		ft/sec
Kilowatts		2.6552×10^6		ft lb/hr	Milligrams		0.01543236		grains
Kilowatts		1.3410		horse power	Milligrams		5.64383×10^{-4}		drams (avoirdupois)
Knots/hr		51.479		cm/sec	Milligrams		2.57206×10^{-4}		drams (troy)
Knots/hr		1.15155		mi/hr	Milligrams		3.52739×10^{-5}		ounces (avoirdupois)
Lamberts		0.3183		candles/sq cm	Milligrams		3.215074×10^{-5}		ounces (troy)
Lamberts		2.054		candles/sq in.	Milligrams		2.2046×10^{-6}		pounds (avoirdupois)
Lamberts		1		lumens emitted/sq cm (perfectly diffusing surface)	Milligrams		2.67923×10^{-6}		pounds (troy)
Liter atmospheres (normal)		24.206		gram calories (mean)	Milligrams/in.		0.38609		dynes/cm
Liter atmospheres (normal)		0.035316		cu ft atm	Milligrams/L		1.0		parts per million
Liters		0.028378		bushels (U.S.)	Milligrams/mm		9.80665		dynes/cm
Liters		0.035316		cu ft	Millilamberts		0.929		lumens emitted/sq ft (with perfect diffusion)
Liters		61.025		cu in.	Milliliters		1.000027		cu cm
Liters		0.001000027		cu m	Milliliters		0.061025		cu in.
Liters		0.0013080		cu yd	Milliliters		0.2705179		drams (U.S., fluid)
Liters		270.5179		drams (U.S., fluid)	Milliliters		16.2311		minims (U.S.)
Liters		0.26417762		gallons (U.S.)	Milliliters		0.0338147		ounces (U.F., fluid)
Liters		33.8143		ounces (U.S., fluid)	Milliliters		0.0393700		inches (U.S.)
Liters		1.816192		pints (U.S., dry)	Millimeters Hg at 0°C		0.00131579		atm
Liters		2.11336		pints (U.S., liquid)	Millimeters Hg at 0°C		1333.22		dynes/sq cm
Liters		0.908096		quarts (U.S., dry)	Millimeters Hg at 0°C		1.3595		g/sq cm
Liters		1.056681869		quarts (U.S., liquid)	Millimeters Hg at 0°C		13.595		kg/sq m
Liters/cm/da		0.011574		sq cm/sec	Millimeters Hg at 0°C		1000		microns Hg at 0°C
Liters/min		5.886×10^{-4}		cu ft/sec	Millimeters Hg at 0°C		2.7845		lb/sq ft
Liters/min		0.004403		gal/sec	Millimeters Hg at 0°C		0.019337		lb/sq in.
Liters/sec		2.11896		cu ft/min	Millimicrons (micro-millimeters)		10		angstrom units
Liters/sec		15.8507		gallons (U.S.)/min	Millimicrons		1×10^{-7}		centimeters
Lumens		0.001496		watts	Minims (U.S., fluid)		0.061612		cubic cm
Lumens/sq ft		1		foot candles	Minims (U.S.)		61.612		cubic cm
Lumens/sq ft		10.764		lumens/sq m	Minims (U.S.)		1/60		drams (U.S., fluid)
Lumens/sq m		0.092902		foot candles (lumens)/sq ft	Minims (U.S.)		0.0616102		milliliters
Lumens/sq m		1×10^{-4}		photos	Minutes (time)		1/480		ounces (U.S., fluid)
Megmhos		0.001		abmhos	Minutes (time)		6.9444×10^{-4}		days
Megmhos		2.540		megmhos/cu in.	Months (mean calendar)		9.9206×10^{-5}		weeks
Megmhos/cu in.		0.39370		megmhos/cu cm	Months (mean calendar)		30.4202		days
Mercury at 0°C		13.5951		g/cu cm	Months (mean calendar)		730.085		hours
Meter candles		1.000		lumens/sq m	Months (mean calendar)		43805.1		minutes
Meters		1×10^{10}		angstrom units	Months (mean calendar)		2.6283×10^6		seconds
Meters		3.280833333		feet (U.S.)	Oersteds (Abs.)		1.00052		oersteds (International)
Meters		39.3700		inches (U.S.)	Ohm-mile-pounds		1.7513×10^{-4}		ohm-meter-grams
Meters		5.39593×10^{-4}		miles (nautical)	Ohms (Abs.)		0.99948		ohms (International)
Meters		6.2137×10^{-4}		miles (statute)	Ounces (avoirdupois)		16		drams (avoirdupois)
Meters		1×10^9		millimicrons	Ounces (avoirdupois)		7.29166		drams (troy or apoth.)
Meters		1×10^{12}		millionth microns	Ounces (avoirdupois)		437.5		grains
Meters		1.55316412×10^6		wave lengths of the red line of cadmium	Ounces (avoirdupois)		28.349527		grams
Meters		1.093611		yards (U.S.)	Ounces (avoirdupois)		0.9114583		ounces (troy or apoth.)
Meters/min		1.6667		cm/sec	Ounces (avoirdupois)		1/16		pounds (avoirdupois)
Meters/min		0.05468		ft/sec	Ounces (avoirdupois)		0.075954861		pounds (troy)
Meters/min		0.06		km/hr	Ounces (troy or apoth.)		17.55428		drams (avoirdupois)
Meters/min		0.03728		mi/hr	Ounces (troy or apoth.)		8		drams (troy or apoth.)
Meters/sec		196.8		ft/min	Ounces (troy or apoth.)		480		grains
Meters/sec		3.6000		km/hr	Ounces (troy or apoth.)		31.103481		grams
Meters/sec		0.060000		km/min	Ounces (troy or apoth.)		1.09714		grams
Meters/sec		2.2369		mi/hr	Ounces (troy or apoth.)		0.06857143		ounces (avoirdupois)
Meters/sec		0.03728		mi/min	Ounces (troy or apoth.)		1/12		pounds (avoirdupois)
Meters/sec ²		3.6		km/hr/sec	Ounces (troy or apoth.)		29.5737		pounds (troy)
Meters/sec ²		2.2369		mi/hr/sec	Ounces (U.S., fluid)		1.80469		cu cm
					Ounces (U.S., fluid)		8		cu in.
					Ounces (U.S., fluid)		1/128		drams (fluid)
					Ounces (U.S., fluid)		0.0295729		gallons (U.S.)
					Ounces (U.S., fluid)		480		liters
					Ounces (U.S., fluid)		1/16		minims (U.S.)
					Ounces (U.S., fluid)				pints (U.S., liquid)

CONVERSION FACTORS (Continued)

Column A	×	Column B	=	Column C	×	Column B	=	Column C
Pints (U.S., dry)	0.015625			bushels (U.S.)	0.038889			cubic ft
Pints (U.S., dry)	550.61			cu cm	67.2006			cubic in.
Pints (U.S., dry)	33.6003			cu in.	1.10120			liters
Pints (U.S., dry)	0.550599			liters	0.125			pecks (U.S.)
Pints (U.S., dry)	0.5			quarts (U.S., dry)	2			pints (dry)
Pints (U.S., liquid)	473.179			cu cm	946.358			cubic cm
Pints (U.S., liquid)	0.016711			cu ft	57.749			cubic in.
Pints (U.S., liquid)	28.875			cu in.	0.033420			cu ft
Pints (U.S., liquid)	6.1881 x 10 ⁻⁴			cu yd	256.00			drams (fluid)
Pints (U.S., liquid)	128			drams (fluid)	0.25			gallons (U.S.)
Pints (U.S., liquid)	0.125			gallons (U.S.)	0.946333			liters
Pints (U.S., liquid)	0.473168			liters	32			ounces (fluid, U.S.)
Pints (U.S., liquid)	7680			minims (U.S.)	1.96841			quintals (metric)
Pints (U.S., liquid)	16			ounces (U.S., fluid)	0.0010764			sq ft
Pints (U.S., liquid)	0.5			quarts (U.S., liquid)	0.15500			sq in.
Planck's quanta	6.554 x 10 ⁻²⁷			erg seconds	0.00247107			sq. links (Gunter's)
Poises	1.000			g/cm/sec	1 x 10 ⁻⁴			sq m
Pounds (avoirdupois)	256			drams (avoirdupois)	100			sq mm
Pounds (avoirdupois)	116.6667			drams (troy)	1.1960 x 10 ⁻⁴			sq yd
Pounds (avoirdupois)	4.44852 x 10 ⁵			dynes	1.1574 x 10 ⁻⁵			sq cm/sec
Pounds (avoirdupois)	7000			grains	2.29568 x 10 ⁻⁵			acres
Pounds (avoirdupois)	453.5924277			grams	929.0341			sq cm
Pounds (avoirdupois)	0.4535924277			kilograms	144			sq in.
Pounds (avoirdupois)	16			ounces (avoirdupois)	0.09290341			sq m
Pounds (avoirdupois)	14.5833			ounces (troy)	3.58701 x 10 ⁻⁸			sq mi
Pounds	32.174			poundals	1/9			sq yd (U.S.)
Pounds (avoirdupois)	1.2152778			pounds (troy)	6.4516258			sq cm
Pounds (avoirdupois)	4.464286 x 10 ⁻⁴			tons (long)	1/144			sq ft (U.S.)
Pounds (avoirdupois)	4.5359243 x 10 ⁻⁴			tons (metric)	6.4516258 x 10 ⁻⁴			sq m
Pounds (avoirdupois)	5 x 10 ⁻⁴			tons (short)	1/1296			sq yd (U.S.)
Pounds (troy)	210.6514			drams (avoirdupois)	247.1044			acres (U.S.)
Pounds (troy)	96			drams (troy)	1.0764 x 10 ⁷			sq ft
Pounds (troy)	5760			grains	1 x 10 ⁶			sq m
Pounds (troy)	373.2418			grams	0.3861006			sq mi (U.S.)
Pounds (troy)	13.165714			ounces (avoirdupois)	1.1960 x 10 ⁶			sq yd
Pounds (troy)	12			ounces (troy)	2.471044 x 10 ⁻⁴			acres (U.S.)
Pounds (troy)	0.822857			pounds (avoirdupois)	1 x 10 ⁴			sq cm
Pounds (troy)	3.6735 x 10 ⁻⁴			tons (long)	10.76387			sq ft (U.S.)
Pounds (troy)	3.7324 x 10 ⁻⁴			tons (metric)	1550.0			sq in.
Pounds (troy)	4.1143 x 10 ⁻⁴			tons (short)	1 x 10 ⁻⁶			sq km
Pounds of water (62°F.)	0.016033			cu ft	1 x 10 ⁶			sq mm
Pounds of water	27.68			cu in.	3.8610 x 10 ⁻⁷			sq mi
Pounds of water	0.1198			gallons (U.S.)	1.195985			sq yd (U.S.)
Pounds/cu in.	27.68			g/cu cm	640			acres
Pounds/ft	1.48816			kg/m	2.78784 x 10 ⁷			sq ft
Pounds/in.	178.6			g/cm	2.589998			sq km
Pounds/sq ft (moment of inertia)	4.2140 x 10 ⁵			g/sq cm	2589998			sq m
Pounds/sq ft (moment of inertia)	421.40			kg/sq cm	3.0976 x 10 ⁶			sq yd
Pounds/sq ft (moment of inertia)	144			lb/sq in.	0.01			sq cm
Pound feet (torque)	1.3558 x 10 ⁷			dyne cm	0.0015500			sq in.
Pounds/sq in. (moment of inertia)	2926.4			g/sq cm	1 x 10 ⁻⁶			sq m
Pounds/sq in. (moment of inertia)	2.9264			kg/sq cm	6.4516 x 10 ⁻⁶			sq cm
Pounds/sq in. (moment of inertia)	0.00694444			lb/sq ft	1 x 10 ⁻⁶			sq in.
Pound inches (torque)	1.1298 x 10 ⁶			dyne cm	6.4516 x 10 ⁻⁴			sq mm
Pounds of water/min	0.016021			cu ft/min	2.06612 x 10 ⁻⁴			acres (U.S.)
Pounds of water/min	2.670 x 10 ⁻⁴			cu ft/sec	8361.31			sq ft
Pounds/cu ft	0.016018			g/cu cm	9			sq in.
Pounds/cu ft	16.018			kg/cu m	1296			sq m
Pounds/cu ft	5.787 x 10 ⁻⁴			lb/cu in.	0.83613			sq mi
Pounds/cu in.	27.6800			kg/cu cm	3.22831 x 10 ⁻⁷			ampere (Abs.)
Pounds/cu in.	2.768 x 10 ⁴			g/cu cm	3.33560 x 10 ⁻¹⁰			coulombs (Abs.)
Pounds/gal (British)	0.099776			g/cu cm	2.0947 x 10 ⁹			electronic charges
Pounds/gal (U.S.)	0.119826			g/cu cm	1.0197 x 10 ⁻⁶			statcoulombs/dyne
Pounds/sq ft	4.7252 x 10 ⁻⁴			atm	2.2481 x 10 ⁻⁶			statcoulombs/dyne
Pounds/sq ft	478.78			dynes/sq cm	1.11263 x 10 ⁻¹²			farads (Abs.)
Pounds/sq ft	0.016018			ft of water at 39.1°F	8.98776 x 10 ¹¹			henries (Abs.)
Pounds/sq ft	0.48824			kg/sq cm	1.11263 x 10 ⁻¹²			mohs, International/cu
Pounds/sq ft	4.8824			kg/sq m	8.98776 x 10 ¹¹			cm
Pounds/sq ft	0.35913			mm of Hg at 0°C	299.796			ohms (Abs.)
Pounds/sq ft	0.0069445			lb/sq in.	1016.0470			volts (Abs.)
Pounds/sq in.	0.068046			atm	2240			kilograms
Pounds/sq in.	68946			dynes/sq cm	2722.22			pounds (avoirdupois)
Pounds/sq in.	70.307			g/sq cm	1000			pounds (troy)
Pounds/sq in.	27.673			in. of water at 39.2°F (4°C)	2204.62			kilograms
Pounds/sq in.	0.070307			kg/sq cm	8.8964 x 10 ⁸			pounds (avoirdupois)
Pounds/sq in.	703.07			kg/sq m	907.1846			dynes
Pounds/sq in.	51.715			mm of Hg	2000			kilograms
Pounds/sq in.	144			lb/sq ft	2430.56			pounds (avoirdupois)
Quarts (U.S., dry)	0.03125			bushels (U.S.)	0.892857			pounds (troy)
Quarts (U.S., dry)	1101.23			cubic cm	0.907185			tons (long)
					0.94509			tons (metric)
					1 x 10 ⁸			atmospheres
					1.0000			abvolts
					0.0033356			joules/coulomb/°C
					0.99955			statvolts
								volts (International)

CONVERSION FACTORS (Concluded)

Column A	×	Column B	=	Column C	Column A	×	Column B	=	Column C
Watt hours		3.4130		BTU (mean)	Watts (Abs.)		1		joules/sec
Watt hours		860.01		calories, g (mean)	Watts (International)		1.00032		watts (Abs.)
Watt hours		0.86001		Calories, kg (mean)	Watts/sq in.		8.1913		BTU/sq ft/min
Watt hours		2655.3		foot pounds	Watts/sq in.		6372.6		ft lb/sq ft/min
Watt hours		0.0013410		horse power hr	Watts/sq in.		0.19310		horse power
Watt hours		3600		joules	Weeks		168		hours
Watt hours		367.09		kg meters	Weeks		10080		minutes
Watts (Abs.)		0.014333		Calories, kg (mean)/min	Weeks		604800		seconds
Watts (Abs.)		1 x 10 ⁷		ergs/sec	Yards (U.S.)		91.440183		centimeters
Watts (Abs.)		44.254		ft lb/min	Yards (U.S.)		5.68182 x 10 ⁻⁴		miles
Watts (Abs.)		0.73756		ft lb/sec	Years (sidereal)		365.256		days (mean solar)
Watts (Abs.)		0.0013410		horse power	Years (sidereal)		8766.144		hours (mean solar)
Watts (Abs.)		0.0013596		horse power (metric)					

ATOMIC WEIGHTS

Values in brackets are mass numbers of most stable isotopes.

Values in brackets are mass numbers of most stable isotope.																
Element	Symbol	Atomic		Element	Symbol	Atomic		Element	Symbol	Atomic		Element	Symbol	Atomic		
		No.	Wt.			No.	Wt.			No.	Wt.			No.	Wt.	
Actinium	Ac	89	227	Erbium	Er	68	167.2	Neodymium	Nd	60	144.27	Scandium	Sc	21	44.96	
Aluminum	Al	13	26.98	Europium	Eu	63	152.0	Neon	Ne	10	20.183	Selenium	Se	34	78.96	
Americium	Am	95	[241]	Fluorine	F	9	19.00	Neptunium	Np	93	[237]	Silicon	Si	14	28.09	
Antimony	Sb	51	121.76	Francium	Fr	87	[223]	Nickel	Ni	28	58.69	Silver	Ag	47	107.86	
Argon	A	18	39.944	Gadolinium	Gd	64	156.9	Niobium	(Columbium)	Nb	41	92.91	Sodium	Na	11	22.99
Arsenic	As	33	74.91	Gallium	Ga	31	69.72	Strontium					Sr	38	87.63	
Astatine	At	85	[210]	Germanium	Ge	32	72.60	Nitrogen	N	7	14.008	Sulfur	S	16	32.06	
Barium	Ba	56	137.36	Gold	Au	79	197.2	Osmium	Os	76	190.2	Tantalum	Ta	73	180.88	
Berkelium	Bk	97	[243]	Hafnium	Hf	72	178.6	Oxygen	O	8	16.0000	Technetium	Tc	43	[99]	
Beryllium	Be	4	9.013	Helium	He	2	4.003	Palladium	Pd	46	106.7	Tellurium	Te	52	127.61	
Bismuth	Bi	83	209.00	Holmium	Ho	67	164.94	Phosphorus	P	15	30.975	Terbium	Tb	65	159.2	
Boron	B	5	10.82	Hydrogen	H	1	1.0080	Platinum	Pt	78	195.23	Thallium	Tl	81	204.39	
Bromine	Br	35	79.916	Indium	In	49	114.76	Plutonium	Pu	94	[239]	Thorium	Th	90	232.12	
Cadmium	Cd	48	112.41	Iodine	I	53	126.91	Polonium	Po	84	210	Thulium	Tm	69	169.4	
Calcium	Ca	20	40.08	Iridium	Ir	77	193.1	Potassium	K	19	39.100	Tin	Sn	50	118.70	
Californium	Cf	98	[244]	Iron	Fe	26	55.85	Praseodymium	Pr	59	140.92	Titanium	Ti	22	47.90	
Carbon	C	6	12.010	Krypton	Kr	36	83.80	Promethium	Pm	61	[147]	Tungsten	(Wolfram)	W	74	183.92
Cerium	Ce	58	140.13	Lanthanum	La	57	138.92	Protactinium	Pa	91	231					
Cesium	Cs	55	132.91	Lead	Pb	82	207.21	Radium	Ra	88	226.05	Uranium	U	92	238.07	
Chlorine	Cl	17	35.457	Lithium	Li	3	6.940	Radon	Rn	86	222	Vanadium	V	23	50.95	
Chromium	Cr	24	52.01	Lutetium	Lu	71	174.99	Rhenium	Re	75	186.31	Xenon	Xe	54	131.3	
Cobalt	Co	27	58.94	Magnesium	Mg	12	24.32	Rhodium	Rh	45	102.91	Ytterbium	Yb	70	173.04	
Copper	Cu	29	63.54	Manganese	Mn	25	54.93	Rubidium	Rb	37	85.48	Yttrium	Y	39	88.92	
Curium	Cm	96	[242]	Mercury	Hg	80	200.61	Ruthenium	Ru	44	101.7	Zinc	Zn	30	65.38	
Dysprosium	Dy	66	162.46	Molybdenum	Mo	42	95.95	Samarium	Sm	62	150.43	Zirconium	Zr	40	91.22	

WEIGHTS OF MULTIPLES

C = 12.01	H = 1.008	O = 16.000	N = 14.008	S = 32.066	P = 30.975	K = 39.100	Na = 22.997	Ca = 40.08	Mg = 24.32
2C = 24.02	2H = 2.016	2O = 32.000	2N = 28.016	2S = 64.132	2P = 61.950	2K = 78.200	2Na = 45.994	2Ca = 80.16	2Mg = 48.64
3C = 36.03	3H = 3.024	3O = 48.000	3N = 42.024	3S = 96.198	3P = 92.925	3K = 117.300	3Na = 68.991	3Ca = 120.24	3Mg = 72.96
4C = 48.04	4H = 4.032	4O = 64.000	4N = 56.032	4S = 128.264	4P = 123.900	4K = 156.400	4Na = 91.998	4Ca = 160.32	4Mg = 97.28
5C = 60.05	5H = 5.040	5O = 80.000	5N = 70.040	5S = 160.330	5P = 154.875	5K = 195.500	5Na = 118.985	5Ca = 200.40	5Mg = 121.60
6C = 72.06	6H = 6.048	6O = 96.000	6N = 84.048	6S = 192.396	6P = 185.850	6K = 234.600	6Na = 137.982	6Ca = 240.48	H ₂ O = 18.016
7C = 84.07	7H = 7.056	7O = 112.000	7N = 98.056	7S = 224.462	7P = 216.825	7K = 273.700	7Na = 160.979	7Ca = 280.56	2H ₂ O = 36.032
8C = 96.08	8H = 8.064	8O = 128.000	8N = 112.064	8S = 256.528	8P = 247.800	8K = 312.800	8Na = 183.976	8Ca = 320.64	3H ₂ O = 54.048
9C = 108.09	9H = 9.072	9O = 144.000	9N = 126.072	9S = 288.594	9P = 278.775	9K = 351.900	9Na = 206.973	9Ca = 360.72	4H ₂ O = 72.064
10C = 120.10	10H = 10.080	10O = 160.000	10N = 140.080	10S = 320.660	10P = 309.750	10K = 391.000	10Na = 229.970	10Ca = 400.80	5H ₂ O = 90.080

THERMOMETRIC EQUIVALENTS

$$F = \frac{9C}{5} + 32; C = \frac{5(F-32)}{9}$$

$^{\circ}\text{F} \leftarrow (^{\circ}\text{C})$	Temp.	$(^{\circ}\text{F}) \rightarrow ^{\circ}\text{C}$	$^{\circ}\text{F} \leftarrow (^{\circ}\text{C})$	Temp.	$(^{\circ}\text{F}) \rightarrow ^{\circ}\text{C}$	$^{\circ}\text{F} \leftarrow (^{\circ}\text{C})$	Temp.	$(^{\circ}\text{F}) \rightarrow ^{\circ}\text{C}$	$^{\circ}\text{F} \leftarrow (^{\circ}\text{C})$	Temp.	$(^{\circ}\text{F}) \rightarrow ^{\circ}\text{C}$
-40.0	- 40	-40.00	+35.6	+2	-16.67	+82.4	+28	-2.22	+129.2	+54	+12.22
-36.4	- 38	-38.89	+37.4	+3	-16.11	+84.2	+29	-1.67	+131.0	+55	+12.78
-32.8	- 36	-37.78	+39.2	+4	-15.56	+86.0	+30	-1.11	+132.8	+56	+13.33
-29.2	- 34	-36.67	+41.0	+5	-15.00	+87.8	+31	-0.56	+134.6	+57	+13.89
-25.6	- 32	-35.56	+42.8	+6	-14.44	+89.6	+32	± 0.00	+136.4	+58	+14.44
-22.0	- 30	-34.44	+44.6	+7	-13.89	+91.4	+33	+0.56	+138.2	+59	+15.00
-18.4	- 28	-33.33	+46.4	+8	-13.33	+93.2	+34	+1.11	+140.0	+60	+15.56
-14.8	- 26	-32.22	+48.2	+9	-12.78	+95.0	+35	+1.67	+141.8	+61	+16.11
-11.2	- 24	-31.11	+50.0	+10	-12.22	+96.8	+36	+2.22	+143.6	+62	+16.67
-7.6	- 22	-30.00	+51.8	+11	-11.67	+98.6	+37	+2.78	+145.4	+63	+17.22
-4.0	- 20	-28.89	+53.6	+12	-11.11	+100.4	+38	+3.33	+147.2	+64	+17.78
-0.4	- 18	-27.78	+55.4	+13	-10.56	+102.2	+39	+3.89	+149.0	+65	+18.33
+3.2	- 16	-26.67	+57.2	+14	-10.00	+104.0	+40	+4.44	+150.8	+66	+18.89
+6.8	- 14	-25.56	+59.0	+15	-9.44	+105.8	+41	+5.00	+152.6	+67	+19.44
+10.4	- 12	-24.44	+60.8	+16	-8.89	+107.6	+42	+5.56	+154.4	+68	+20.00
+14.0	- 10	-23.33	+62.6	+17	-8.33	+109.4	+43	+6.11	+156.2	+69	+20.56
+17.6	- 8	-22.22	+64.4	+18	-7.78	+111.2	+44	+6.67	+158.0	+70	+21.11
+19.4	- 7	-21.67	+66.2	+19	-7.22	+113.0	+45	+7.22	+159.8	+71	+21.67
+21.2	- 6	-21.11	+68.0	+20	-6.67	+114.8	+46	+7.78	+161.6	+72	+22.22
+23.0	- 5	-20.56	+69.8	+21	-6.11	+116.6	+47	+8.33	+163.4	+73	+22.78
+24.8	- 4	-20.00	+71.6	+22	-5.56	+118.4	+48	+8.89	+165.2	+74	+23.33
+26.6	- 3	-19.44	+73.4	+23	-5.00	+120.2	+49	+9.44	+167.0	+75	+23.89
+28.4	- 2	-18.89	+75.2	+24	-4.44	+122.0	+50	+10.00	+168.8	+76	+24.44
+30.2	- 1	-18.33	+77.0	+25	-3.89	+123.8	+51	+10.56	+170.6	+77	+25.00
+32.0	+ 0	-17.78	+78.8	+26	-3.33	+125.6	+52	+11.11	+172.4	+78	+25.56
+33.8	+ 1	-17.22	+80.6	+27	-2.78	+127.4	+53	+11.67	+174.2	+79	+26.11

THERMOMETRIC EQUIVALENTS (Concluded)											
°F ← (°C) Temp. (°F) → °C	°F ← (°C) Temp. (°F) → °C	°F ← (°C) Temp. (°F) → °C	°F ← (°C) Temp. (°F) → °C	°F ← (°C) Temp. (°F) → °C	°F ← (°C) Temp. (°F) → °C	°F ← (°C) Temp. (°F) → °C	°F ← (°C) Temp. (°F) → °C	°F ← (°C) Temp. (°F) → °C	°F ← (°C) Temp. (°F) → °C	°F ← (°C) Temp. (°F) → °C	°F ← (°C) Temp. (°F) → °C
+176.0	+80	+26.67	+237.2	+114	+45.56	+298.4	+148	+64.44	+359.6	+182	+83.33
+177.8	+81	+27.22	+239.0	+115	+46.11	+300.2	+149	+65.00	+361.4	+183	+83.89
+179.6	+82	+27.78	+240.8	+116	+46.67	+302.0	+150	+65.56	+363.2	+184	+84.44
+181.4	+83	+28.33	+242.6	+117	+47.22	+303.8	+151	+66.11	+365.0	+185	+85.00
+183.2	+84	+28.89	+244.4	+118	+47.78	+305.6	+152	+66.67	+366.8	+186	+85.56
+185.0	+85	+29.44	+246.2	+119	+48.33	+307.4	+153	+67.22	+368.6	+187	+86.11
+186.8	+86	+30.00	+248.0	+120	+48.89	+309.2	+154	+67.78	+370.4	+188	+86.67
+188.6	+87	+30.56	+249.8	+121	+49.44	+311.0	+155	+68.33	+372.2	+189	+87.22
+190.4	+88	+31.11	+251.6	+122	+50.00	+312.8	+156	+68.89	+374.0	+190	+87.78
+192.2	+89	+31.67	+253.4	+123	+50.56	+314.6	+157	+69.44	+375.8	+191	+88.33
+194.0	+90	+32.22	+255.2	+124	+51.11	+316.4	+158	+70.00	+377.6	+192	+88.89
+195.8	+91	+32.78	+257.0	+125	+51.67	+318.2	+159	+70.56	+379.4	+193	+89.44
+197.6	+92	+33.33	+258.8	+126	+52.22	+320.0	+160	+71.11	+381.2	+194	+90.00
+199.4	+93	+33.89	+260.6	+127	+52.78	+321.8	+161	+71.67	+383.0	+195	+90.56
+201.2	+94	+34.44	+262.4	+128	+53.33	+323.6	+162	+72.22	+384.8	+196	+91.11
+203.0	+95	+35.00	+264.2	+129	+53.89	+325.4	+163	+72.78	+386.6	+197	+91.67
+204.8	+96	+35.56	+266.0	+130	+54.44	+327.2	+164	+73.33	+388.4	+198	+92.22
+206.6	+97	+36.11	+267.8	+131	+55.00	+329.0	+165	+73.89	+390.2	+199	+92.78
+208.4	+98	+36.67	+269.6	+132	+55.56	+330.8	+166	+74.44	+392.0	+200	+93.33
+210.2	+99	+37.22	+271.4	+133	+56.11	+332.6	+167	+75.00	+393.8	+201	+93.89
+212.0	+100	+37.78	+273.2	+134	+56.67	+334.4	+168	+75.56	+395.6	+202	+94.44
+213.8	+101	+38.33	+275.0	+135	+57.22	+336.2	+169	+76.11	+397.4	+203	+95.00
+215.6	+102	+38.89	+276.8	+136	+57.78	+338.0	+170	+76.67	+399.2	+204	+95.56
+217.4	+103	+39.44	+278.6	+137	+58.33	+339.8	+171	+77.22	+401.0	+205	+96.11
+219.2	+104	+40.00	+280.4	+138	+58.89	+341.6	+172	+77.78	+402.8	+206	+96.67
+221.0	+105	+40.56	+282.2	+139	+59.44	+343.4	+173	+78.33	+404.6	+207	+97.22
+222.8	+106	+41.11	+284.0	+140	+60.00	+345.2	+174	+78.89	+406.4	+208	+97.78
+224.6	+107	+41.67	+285.8	+141	+60.56	+347.0	+175	+79.44	+408.2	+209	+98.33
+226.4	+108	+42.22	+287.6	+142	+61.11	+348.8	+176	+80.00	+410.0	+210	+98.89
+228.2	+109	+42.78	+289.4	+143	+61.67	+350.6	+177	+80.56	+411.8	+211	+99.44
+230.0	+110	+43.33	+291.2	+144	+62.22	+352.4	+178	+81.11	+413.6	+212	+100.00
+231.8	+111	+43.89	+293.0	+145	+62.78	+354.2	+179	+81.67	+415.4	+213	+100.56
+233.6	+112	+44.44	+294.8	+146	+63.33	+356.0	+180	+82.22	+417.2	+214	+101.11
+235.4	+113	+45.00	+296.6	+147	+63.89	+357.8	+181	+82.78	+419.0	+215	+101.67

APPENDIX V: LOGARITHMS AND ANTILOGARITHMS

FOUR-PLACE LOGARITHMS																														
N										Proportional Parts					N										Proportional Parts					
0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4	8	12	17	21	55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	7482	7490	7497	7505
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4	8	11	15	19	56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	7559	7566	7574	7582
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3	7	10	14	17	57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	7634	7642	7649	7657
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3	6	10	13	16	58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	7709	7716	7723	7731
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3	6	9	12	15	59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	7781	7788	7796	7803
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3	6	8	11	14	60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	7853	7860	7868	7875
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3	5	8	11	13	61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	7924	7931	7938	7945
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2	5	7	10	12	62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	7994	8001	8007	8014
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2	5	7	9	12	63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	8062	8069	8075	8082
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2	4	7	9	11	64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	8129	8136	8142	8149
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2	4	6	8	11	65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	8195	8202	8209	8215
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2	4	6	8	10	66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	8261	8267	8274	8280
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2	4	6	8	10	67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	8325	8331	8338	8344
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2	4	6	7	9	68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	8388	8395	8401	8407
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2	4	5	7	9	69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	8451	8457	8463	8470
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2	3	5	7	9	70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	8512	8519	8525	8531
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2	3	5	7	8	71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	8573	8579	8585	8591
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2	3	5	6	8	72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	8633	8639	8645	8651
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2	3	5	6	7	83	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	8692	8698	8704	8710
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1	3	4	6	7	74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	8751	8757	8762	8768
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1	3	4	6	7	75	8751	8757	8762	8768	8774	8779	8785	8791	8797	8802	8808	8814	8820	8825
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1	3	4	6	7	76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	8865	8871	8876	8882
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1	3	4	5	7	77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	8921	8927	8932	8938
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1	3	4	5	6	78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	8976	8982	8987	8993
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1	3	4	5	6	79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	9030	9036	9042	9047
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1	2	4	5	6	80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	9084	9090	9096	9101
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1	2	4	5	6	81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	9138	9143	9149	9154
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1	2	3	5	6	82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	9191	9196	9202	9207
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1	2	3	5	6	83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	9243	9248	9253	9258
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1	2	3	4	5	84	9248	9248	9253	9258	9263	9269	9274	9279	9284	9289	9294	9299	9304	9309
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1	2	3	4	5	85	9294	9299	9304	9309	9313	9320	9325	9330	9335	9340	9345	9350	9355	9360
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1	2	3	4	5	86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	9395	9400	9405	9410
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1	2	3	4	5	87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	9445	9450	9455	9460
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1	2	3	4	5	88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	9494	9499	9504	9509
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1	2	3	4	5	89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	9543	9548	9553	9558
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1	2	3	4	5	90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	9591	9596	9601	9606
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1	2	3	4	5	91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	9637	9642	9646	9651
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1	2	3	4	5	92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	9684	9689	9693	9698
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1	2	3	4	5	93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	9731	9736	9741	9745
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1	2	3	4	5	94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9772	9777	9781	9786	9790
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1	2	3	4	5	95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	9823	9827	9832	9836
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1	2	3	4	5	96	9823	9827	9832	9836	9841	9845	9849	9854	9858	9863	9867	9872	9876	9881
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1	2	3	4	5	97	9868	9872	9877	9881	9886	9890	9894	9898	9903	9908	9912	9917	9921	9926
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1	2	3	4	5	98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	9957	9961	9966	9970
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1	2	3	4	5	99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9995	9999	10000	10000	10000
N										Proportional Parts					N										Proportional Parts					
0	1	2	3	4	5	6	7	8	9	1	2	3	4	5	0	1	2	3	4	5	6	7	8	9	1	2	3	4		

APPENDIX V: LOGARITHMS AND ANTILOGARITHMS FOUR-PLACE ANTILOGARITHMS

Log											Proportional Parts					Log											Proportional Parts				
	0	1	2	3	4	5	6	7	8	9	1	2	3	4	5		0	1	2	3	4	5	6	7	8	9	1	2	3	4	5
.00	1000	1002	1005	1007	1009	1012	1014	1016	1019	1021	0	0	1	1	1	.50	3162	3170	3177	3184	3192	3199	3206	3214	3221	3228	1	1	2	3	4
.01	1023	1026	1028	1030	1033	1035	1038	1040	1042	1045	0	0	1	1	1	.51	3236	3243	3251	3258	3266	3273	3281	3289	3296	3304	1	2	2	3	4
.02	1047	1050	1052	1054	1057	1059	1062	1064	1067	1069	0	0	1	1	1	.52	3311	3319	3327	3334	3342	3350	3357	3365	3373	3381	1	2	2	3	4
.03	1072	1074	1076	1079	1081	1084	1086	1089	1091	1094	0	0	1	1	1	.53	3388	3396	3404	3412	3420	3428	3436	3443	3451	3459	1	2	2	3	4
.04	1096	1099	1102	1104	1107	1109	1112	1114	1117	1119	0	1	1	1	1	.54	3467	3475	3483	3491	3499	3508	3516	3524	3532	3540	1	2	2	3	4
.05	1122	1125	1127	1130	1132	1135	1138	1140	1143	1146	0	1	1	1	1	.55	3548	3556	3565	3573	3581	3589	3597	3606	3614	3622	1	2	2	3	4
.06	1148	1151	1153	1156	1159	1161	1164	1167	1169	1172	0	1	1	1	1	.56	3631	3639	3648	3656	3664	3673	3681	3690	3698	3707	1	2	2	3	4
.07	1175	1178	1180	1183	1186	1189	1191	1194	1197	1199	0	1	1	1	1	.57	3715	3724	3733	3741	3750	3758	3767	3776	3784	3793	1	2	2	3	4
.08	1202	1205	1208	1211	1213	1216	1219	1222	1225	1227	0	1	1	1	1	.58	3802	3811	3819	3828	3837	3846	3855	3864	3873	3882	1	2	2	3	4
.09	1230	1233	1236	1239	1242	1245	1247	1250	1253	1256	0	1	1	1	1	.59	3890	3899	3908	3917	3926	3936	3945	3954	3963	3972	1	2	2	3	4
.10	1259	1262	1265	1268	1271	1274	1276	1279	1282	1285	0	1	1	1	1	.60	3981	3990	3999	4009	4018	4027	4036	4046	4055	4064	1	2	2	3	4
.11	1288	1291	1294	1297	1300	1303	1306	1309	1312	1315	0	1	1	1	2	.61	4074	4083	4093	4102	4111	4121	4130	4140	4150	4159	1	2	2	3	4
.12	1318	1321	1324	1327	1330	1334	1337	1340	1343	1346	0	1	1	1	2	.62	4169	4178	4188	4198	4207	4217	4227	4236	4246	4256	1	2	2	3	4
.13	1349	1352	1355	1358	1361	1365	1368	1371	1374	1377	0	1	1	1	2	.63	4266	4276	4285	4295	4305	4315	4325	4335	4345	4355	1	2	2	3	4
.14	1380	1384	1387	1390	1393	1396	1400	1403	1406	1409	0	1	1	1	2	.64	4365	4375	4385	4395	4406	4416	4426	4436	4446	4457	1	2	2	3	4
.15	1413	1416	1419	1422	1426	1429	1432	1435	1439	1442	0	1	1	1	2	.65	4467	4477	4487	4498	4508	4519	4529	4539	4550	4560	1	2	2	3	4
.16	1445	1449	1452	1455	1459	1462	1466	1469	1472	1476	0	1	1	1	2	.66	4517	4528	4538	4549	4560	4571	4582	4593	4604	4615	1	2	2	3	4
.17	1479	1483	1486	1489	1493	1496	1500	1503	1507	1510	0	1	1	1	2	.67	4677	4688	4699	4710	4721	4732	4742	4753	4764	4775	1	2	2	3	4
.18	1514	1517	1521	1524	1528	1531	1535	1538	1542	1545	0	1	1	1	2	.68	4786	4797	4808	4819	4831	4842	4853	4864	4875	4887	1	2	2	3	4
.19	1549	1552	1556	1560	1563	1567	1570	1574	1578	1581	0	1	1	1	2	.69	4898	4909	4920	4932	4943	4955	4966	4977	4989	5000	1	2	2	3	4
.20	1585	1589	1592	1596	1600	1603	1607	1611	1614	1618	0	1	1	1	2	.70	5012	5023	5035	5047	5058	5070	5082	5093	5105	5117	1	2	2	3	4
.21	1622	1626	1629	1633	1637	1641	1644	1648	1652	1656	0	1	1	1	2	.71	5129	5140	5152	5164	5176	5188	5200	5212	5224	5236	1	2	2	3	4
.22	1660	1663	1667	1671	1675	1679	1683	1687	1690	1694	0	1	1	1	2	.72	5248	5260	5272	5284	5297	5309	5321	5333	5346	5358	1	2	2	3	4
.23	1698	1702	1706	1710	1714	1718	1722	1726	1730	1734	0	1	1	1	2	.73	5370	5383	5395	5408	5420	5433	5445	5458	5470	5483	1	2	2	3	4
.24	1738	1742	1746	1750	1754	1758	1762	1766	1770	1774	0	1	1	1	2	.74	5495	5508	5521	5534	5546	5559	5572	5585	5598	5610	1	2	2	3	4
.25	1778	1782	1786	1791	1795	1799	1803	1807	1811	1816	0	1	1	1	2	.75	5623	5636	5649	5662	5675	5689	5702	5715	5728	5741	1	2	2	3	4
.26	1820	1824	1828	1832	1837	1841	1845	1849	1854	1858	0	1	1	1	2	.76	5754	5768	5781	5794	5808	5821	5834	5848	5861	5875	1	2	2	3	4
.27	1862	1866	1871	1875	1879	1884	1888	1892	1897	1901	0	1	1	1	2	.77	5888	5902	5916	5929	5943	5957	5970	5984	5998	6012	1	2	2	3	4
.28	1905	1910	1914	1919	1923	1928	1932	1936	1941	1945	0	1	1	1	2	.78	6026	6039	6053	6067	6081	6095	6109	6124	6138	6152	1	2	2	3	4
.29	1950	1954	1959	1963	1968	1972	1977	1982	1986	1991	0	1	1	1	2	.79	6166	6180	6194	6209	6223	6237	6252	6266	6281	6295	1	2	2	3	4
.30	1995	2000	2004	2009	2014	2018	2023	2028	2032	2037	0	1	1	1	2	.80	6310	6324	6339	6353	6368	6383	6397	6412	6427	6442	1	2	2	3	4
.31	2042	2046	2051	2056	2061	2065	2070	2075	2080	2084	0	1	1	1	2	.81	6457	6471	6486	6501	6516	6531	6546	6561	6577	6592	1	2	2	3	4
.32	2089	2094	2099	2104	2109	2113	2118	2123	2128	2133	0	1	1	1	2	.82	6607	6622	6637	6653	6668	6683	6699	6714	6730	6745	1	2	2	3	4
.33	2138	2143	2148	2153	2158	2163	2168	2173	2178	2183	0	1	1	1	2	.83	6761	6776	6792	6808	6823	6839	6855	6871	6887	6902	1	2	2	3	4
.34	2188	2193	2198	2203	2208	2213	2218	2223	2228	2234	1	1	1	1	2	.84	6918	6934	6950	6966	6982	6998	7015	7031	7047	7063	1	2	2	3	4
.35	2239	2244	2249	2254	2259	2265	2270	2275	2280	2286	1	1	1	1	2	.85	7079	7096	7112	7129	7145	7161	7178	7194	7211	7228	1	2	2	3	4
.36	2291	2296	2301	2307	2312	2317	2323	2328	2333	2339	1	1	1	1	2	.86	7244	7261	7278	7295	7311	7328	7345	7362	7379	7396	1	2	2	3	4
.37	2344	2350	2355	2360	2366	2371	2377	2382	2388	2393	1	1	1	1	2	.87	7413	7430	7447	7464	7482	7499	7516	7534	7551	7568	1	2	2	3	4
.38	2399	2404	2410	2415	2421	2427	2432	2438	2443	2449	1	1	1	1	2	.88	7586	7603	7621	7638	7656	7674	7691	7709	7727	7745	1	2	2	3	4
.39	2455	2460	2466	2472	2477	2483	2489	2495	2500	2506	1	1	1	1	2	.89	7762	7780	7798	7816	7834	7852	7870	7889	7907	7925	1	2	2	3	4
.40	2512	2518	2523	2529	2535	2541	2547	2553	2559	2564	1	1	1	1	2	.90	7943	7962	7980	7998	8017	8035	8054	8072	8091	8110	1	2	2	3	4
.41	2570	2576	2582	2588	2594	2600	2606	2612	2618	2624	1	1	1	1	2	.91	8128	8147	8166	8185	8204	8222	8241	8260	8279	8299	1	2	2	3	4
.42	2630	2636	2642	2649	2655	2661	2667	2673	2679	2685	1	1	1	1	2	.92	8318	8337	8356												

INDEX

This section is comprised of two parts, a Contributor-Reviewer Index and a Subject Index. On pages v - xxx there appears, in alphabetical order, a complete list of contributors and reviewers (not including advisers and members of the Panel of Appraisers), each with an accompanying reference number. In the table of contents each table title is followed, in parentheses, by the reference number(s) of the principal contributor(s) of that table. Single-source tables adapted directly from the literature have no such identifying numbers, but the literature citation is given in the headnote of that table. The Contributor-Reviewer Index lists, by number, all contributors and reviewers for each table. Table numbers are enclosed in "slashes," and are followed by appropriate reference numbers. For example, /1/ 211, 4036 indicates that Table 1, "Standard Solutions: pH_s," was contributed and/or reviewed by Roger G. Bates (number 211) and Claude E. ZoBell (number 4036).

In an attempt to provide as useful a subject index as possible, and at the same time to strive for maximum economy of space, certain expediciencies have been employed. The Subject Index is designed for use in correlation with the table of contents, eliminating the necessity for most of the usual secondary index entries. Because each table title appears in the Contents, such correlation is relatively simple. For example, GLUCOSE is accompanied by many page numbers, among which are (random selection) 8, 17, 52, 233, and 250. The table of contents reveals the following: page 8, characteristics of glucose; 17, glucose as a component of glycosides; 52, glucose content of human blood; 233, glycolytic metabolism of glucose; 250, the role of glucose in photosynthesis.

Effort has been made to index scientific and common names for every organism and every chemical listed in the book. Unfortunately it has been impossible to adhere to anyone standard system of nomenclature for either category--actually, "standard" systems themselves have undergone considerable change during the preparation of the Handbook. Consequently, it was decided that the nomenclature employed within the "text" of the book remain as in the data contributed by the many authorities and authenticated by other experts in the same fields. Wherever ambiguity appeared likely, entries were cross-referenced. Moreover, in most cases, synonyms (trade names, where applicable) and alternate designations accompany the nomenclature used within the tables.

Organisms are indexed down to the genus level. Obviously, a listing of all species would not only quadruple the size of the index, but also would be redundant because in the majority of cases the several species of a given genus are grouped together within any one table. Common names of organisms have been indexed, wherever possible, in two ways, e.g., there is an entry EVERGREEN(S) after which appear the numbers of all pages containing information on evergreens in general; in addition, each evergreen, e.g., PINE(S), SPRUCE(S), FIR(S), is also indexed. Again, in most tables all species of each tree are grouped in alphabetical order.

Indexing of table titles has been held to a minimum, and general subject headings appearing in the index apply to column headings or other sections of tables not directly indicated in the Contents.

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